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PROFILES OF AIR TEMPERATURES NORMAL TO COAST LINES

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IT may probably be assumed that we possess a sufficient understanding of the physical principles by which the difference in daily and annual march between air temperatures over land and over sea may be explained. But the consequences of these principles regarding the distribution of air temperature in the coastal zones of the land, whether deduced logically or identified empirically in the data of observation, have probably not all been drawn. The present article first attempts to deduce the distribution of air temperature over the land along lines normal to coasts under various conditions of temperature of land and water and of wind direction. The results arrived at by deduction are then compared with profiles of means of observed temperature drawn inland from the coast at three places in the United States. The profile is a particularly effective device for exhibiting temperature data from coastal zones. It presents temperature explicitly as a function of horizontal distance from the coast, whereas in cartographic or tabular arrays the dependence of temperature on horizontal distance is manifested less distinctly.

THERMAL EFFECTS ON AIR OF CROSSING A COAST LINE

When the temperatures of adjacent surfaces of land and water differ appreciably, the temperature of air that crosses the coast line from sea to land or from land to sea may be expected to undergo a change. The average monthly temperatures of neighboring surfaces of land and sea are ofte. nearly equal, if one may judge from the mean monthly temperatures of the air above them. For example, in almost all parts of the earth within 30 degrees of the equator, except along cold-water coasts, isotherms of mean air temperature in winter cross coast lines without conspicuous deflection. In summer, the difference in mean air temperature between land and sea is small in high latitudes. The daily range of surface temperature of the land, however, is ordinarily much larger than that of the sea. Hence equality in temperature of the two kinds of surface and of the air above them at the same moment must be an evanescent condition in the daily pendulation of temperature, a condition that would be recorded only infrequently in a random sample of momentary observations.

The representative relation must be one in which there is a significant difference in temperature between adjoining surfaces of land and water, and consequently between the bodies of air that have moved over or rested upon them. Thus air that crosses a coast line usually moves on to a surface with which it is not in thermal equilibrium. A process of heat exchange between the air and the surface over which it has arrived commences immediately. The lowest layers of the atmosphere are warmed or cooled, changing toward a condition of equilibrium in which the difference in temperature between air and underlying surface is minimal. The factors that determine the rate of change in temperature of the lower atmosphere, other than the original difference in temperature between air and terrestrial surface, do not need to be enumerated here.

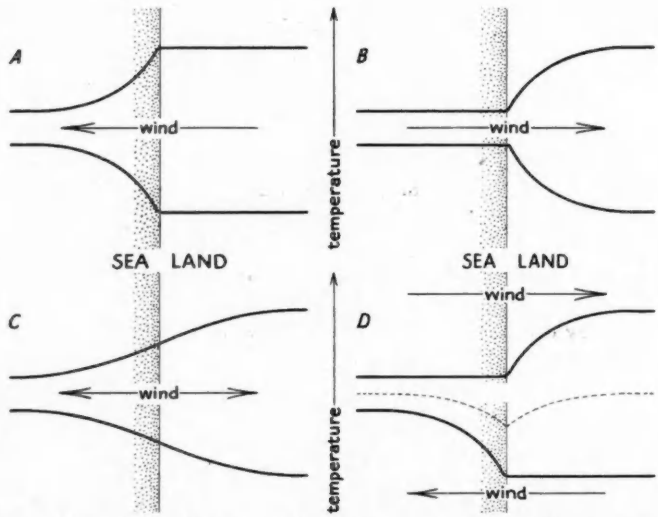

FIG. 1. Profiles of temperature in air blowing across a coast line. The upper curve of each pair represents the gradation of temperature in the coastal zone when the land is warmer than the sea, and the lower curve the gradation when the land is colder than the sea. *A*, offshore wind; *B*, onshore wind; *C*, both offshore and onshore winds; *D*, land-and-sea breezes or monsoons.

Several possibilities in the readjustment of the temperature of surface air after it has passed a coast line are illustrated schematically in Figure 1. The horizontal coördinate in each of the four diagrams is distance on the earth's surface within a belt that includes a strip of land and one of water separated by the coast line. The vertical coördinate is temperature, increasing upward. Except in diagram *C*, the heavy curves represent the temperature of air moving continuously in the directions indicated by the wind arrows. The upper curve in each diagram represents the temperature of the air when the surface of the land is warmer than that of the sea, and the lower curve its temperature when the surface of the land is colder than the sea

surface. Any desired scale may be applied to either coördinate; the difference in air temperature between the adjacent surfaces may therefore be assumed to represent conditions at the extremes of either the daily or the annual cycle, or persistent differences such as obtain between cold coastal water and land in low latitudes or between glaciated land and open sea in high latitudes. The air is assumed to be in thermal equilibrium with the surface in its source region, so that in *A*, *B*, and *D* its temperature is unchanged so long as it remains within that region. It is further assumed that it attains equilibrium with the surface on to which it moves within the horizontal distance included in the diagrams. Hence the curves straighten out and become parallel to the horizontal axis of coördinates, reflecting the attainment of constant temperature, before they are terminated in the direction of the wind.

The greatest difference in temperature between the air and the surface over which it is moving exists just after the air crosses the coast line. The change in temperature of the moving air is therefore most rapid here; as the air approaches equilibrium with the surface, its change in temperature with increasing distance in the direction of its motion becomes less.[1] The four curves in *A* and *B* of Figure 1, then, represent possible profiles of temperature in air moving across a coast line: *A* represents offshore wind and *B* onshore wind. The wind arrows may be interpreted as representing the offshore or onshore components of any wind movement, whether it is steady flow, the average of varying speeds, or temporary cross-currents in horizontal turbulence. In the limiting case of no difference in temperature between land and water surfaces there is no break in the profile of temperature at the coast.

All the momentary profiles of the types drawn in Figure 1, *A* and *B*, that might be observed in a period of record are averaged in the profiles drawn from mean temperatures. If the wind movement across a coast line during a period of record is approximately half offshore and half onshore, the average profiles resemble the curves in *C* of Figure 1. In this condition the transition zone in which the temperature of the air changes toward equilibrium is not restricted to land or to sea, as in *A* and *B*, but extends seaward and inland from the coast. Profiles intermediate in shape between the curves of *C* and those of *A* and *B* may be expected in average data, the form of a particular profile depending on the predominance of offshore or onshore winds.

Thus far the discussion has proceeded as if the difference in temperature between land and water were independent of the direction of wind movement, and hence as if the occurrence of offshore and onshore winds were equally probable whether the land is warmer or cooler than the water surface. But the association of offshore and onshore winds with certain phases of the daily or annual cycle, in land-and-sea breezes

[1] Compare the observed temperatures plotted in Figure 4, p. 199, of John Leighly, "The Extremes of the Annual Temperature March with Particular Reference to California," *Univ. Calif. Publs. in Geog.*, Vol. 6, 1938, pp. 191–234. In the present discussion it is assumed that, with a given difference in temperature between the air and the surface over which it moves, the change in temperature of the air proceeds at the same rate whether it is being warmed or cooled, differing only in algebraic sign.

and in the monsoon components of the general circulation of the atmosphere, is sufficiently frequent to require consideration. Diagram *D* of Figure 1 represents temperature profiles in the two phases of a daily or annual cycle when the wind blows onshore in the warmer phase and offshore in the cooler phase. The upper curve thus refers to conditions in the daytime or summer, the lower one to conditions at night or in winter. Together, the two curves drawn as heavy lines represent the extreme toward which the symmetrical pair of curves in diagram *C* is distorted if the direction of the wind across the coast line departs from random variation in the manner characteristic of land-and-sea breezes or monsoons.

The light broken line in *D* of Figure 1 is drawn halfway between the two heavy curves. It therefore represents the mean of momentary temperatures in a symmetrical oscillation between the extremes marked by the heavy curves. I have drawn it to show a thermal effect of land-and-sea breezes or monsoons that I do not recall having seen recorded. Even when the air blows back and forth across the coast line with perfect regularity, and when the surfaces of land and water have the same average temperature, the mean temperature of the surface air near the coast, over both land and water, is lower than the mean farther inland and at sea. The reduction of temperature, in the coastal zone that is affected by the periodically reversed flow of surface air from the cold to the warm part of the system, is not compensated. The temperature profiles over the land then simulate the profiles inland from cold coastal water, appearing to decline near the coast toward a temperature distinctly lower than that of the land surface. The minimum toward which the curves of maximum and mean temperature actually decline is, however, immediately at the coast, not over the open water.

TEMPERATURE PROFILES IN THE DAILY CYCLE

Although each of the profiles drawn with heavy lines in Figure 1 may be considered independently, each representative of a particular combination of wind direction and difference in temperature between land and water, the pair of curves in each diagram may also represent the profiles of air temperature at the maximum and minimum of a daily or annual march. The difference in range of air temperature between land and water is represented by the difference in distance between the parts of the curves to the right and to the left of the coast line.

In Figure 1 the mean temperatures of the surfaces of land and water, and of the air above them, are assumed equal, except for the distortion of mean air temperature in diagram *D*. Such equality of mean air temperature over neighboring land and water surfaces is, however, a special condition. In a closer approximation to the actual thermal relations of land and water, differences in mean air temperature over the contrasting surfaces must be considered. Figure 2 shows profiles of maximum and minimum air temperatures, and also of the means of a symmetrical pendulation between the extremes, in three cases: *A,* where the mean air temperature is the same over the land as over the neighboring water; *B,* where the mean temperature is lower over the land than over the water; and *C,* where the mean temperature is higher over

the land than over the water. It is assumed in all three cases that offshore and onshore winds are equally frequent. *A* of Figure 2 therefore represents the same conditions as

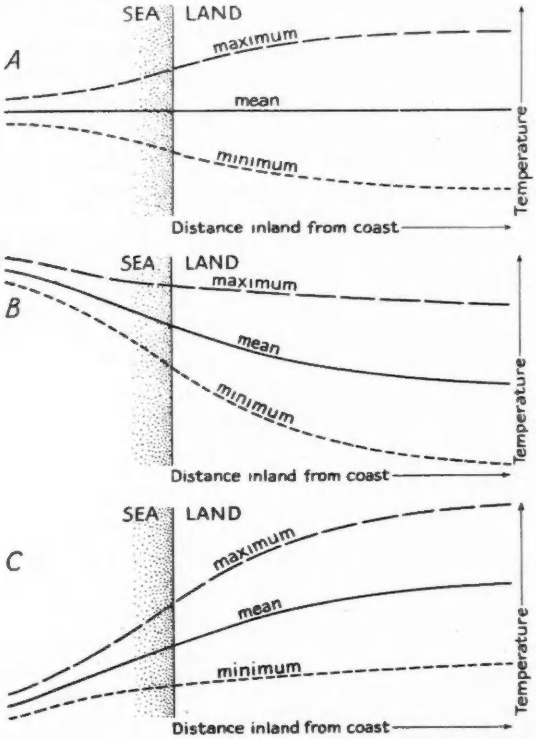

FIG. 2. Profiles of average temperature in a coastal zone with both offshore and onshore winds included in the record. *A*, mean temperatures of sea and land equal; *B*, mean temperature of the land lower than that of the sea; *C*, mean temperature of the land higher than that of the sea.

C of Figure 1. In Figure 2, however, it is not assumed that the air attains thermal equilibrium with the surface over which it moves within the horizontal distance represented. Except for the profile of mean temperature in *A*, therefore, the curves do not straighten out and become parallel to the horizontal axis of coördinates inland or seaward, but only approach a constant temperature asymptotically.

From here on, the profiles in Figure 2 will be considered representative of the daily rather than the annual cycle. In the annual cycle, the marginal belt of a continent in which the transition from marine to continental temperatures is effected is immensely wider than the transitional belt in the daily cycle. It may, in fact, include most or all of the area of a continent. In any event it is so wide that the transition is

likely to be distorted by relief or change of latitude. Profiles of observed temperature that may be compared with the smooth theoretical ones in Figures 1 and 2 are much more likely to be found if the extremes and means of the daily rather than of the annual cycle are examined.

The curves in *B* of Figure 2, then, may be taken as representative of the profiles of daily extreme and mean temperatures in winter, when the surface of the land is colder than the surface of the neighboring water. Those in *C* represent profiles of air temperature in summer, when the land is warmer than the water. *B* is drawn to represent conditions in which the minimum temperature of air in thermal equilibrium with the water surface is slightly higher than the maximum of the air in equilibrium with the land surface. *C* is drawn with a corresponding assumption concerning the temperatures of the two surfaces, but with differences in the opposite sense. It is evident that at either extreme season a great range of difference in temperature between the surfaces of neighboring water and land, in comparison with the daily range, is possible; in any single instance the difference may be greater or less than is represented in *B* and *C* of Figure 2. And in any one locality the difference in mean temperature between land and water may be greater at one season than at the other. Along the Pacific coast of the United States, for example, the difference is much larger in summer than in winter. Along the Atlantic coast it is larger in winter than in summer.

There is a characteristic difference between the profiles of maximum and of minimum temperatures when the mean temperatures of land and water differ appreciably. In winter, the air temperature over the land is moderated more strongly by proximity to the sea at the minimum than at the maximum. In summer, it is more strongly affected at the maximum. This seasonal difference, which results from the small daily range of air temperature over the sea as compared with the daily range over the land, is reflected in Figure 2 by the greater curvature of the "minimum" profile in *B*, and of the "maximum" profile in *C*, than appears in the profiles at the opposite extremes.

Among the three conditions represented in Figure 2 a daily alternation of land and sea breezes in the classical sense is to be expected only in *A*. In *B* the air over the land does not become warm enough in the daytime to permit a sea breeze, and in *C* it does not become cool enough at night to generate a land breeze. *B* and *C* produce fluctuations in strength of the coastal solenoidal field in the daily cycle, but not a reversal of the direction of acceleration within it. In order that the direction of acceleration in the coastal solenoidal field may be reversed twice in the daily cycle, to produce the classical alternation of land and sea breezes, the daily range of air temperature over the land must not only exceed, but must also include the range over the neighboring water. In special instances, however, the superposition of a general wind, onshore in *B* and offshore in *C*, might lead to a daily alternation of direction of movement of air across the coast line.

PROFILES OF OBSERVED TEMPERATURE

The profiles in Figures 1 and 2 are theoretical constructs arrived at deductively; it remains to be seen whether or not they are approximated in the results of observation. Profiles drawn from published averages of temperature observed in three widely separated parts of the United States are reproduced in Figures 3, 4, and 5.[2] Evidently the results of observation at the coöperative stations of the Weather Bureau, in spite of their deficiencies, exemplify the effects exerted by bodies of water on the daily march of temperature in coastal zones and the transition from marine to continental régimes of temperature.

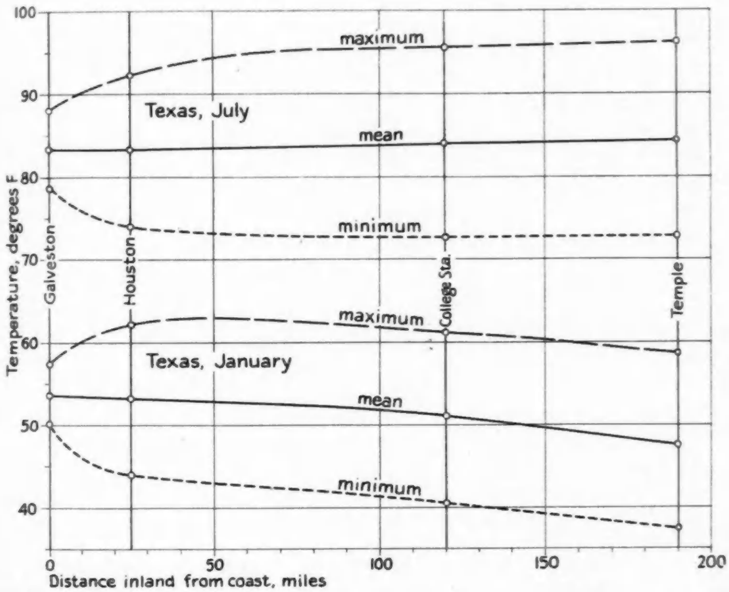

FIG. 3. Profiles of mean maximum, mean, and mean minimum temperatures inland from the Texas coast.

How many profiles smooth enough to be of climatologic value can be drawn from the published temperature records of stations in the coastal zones of the United States I can not say. In the Pacific states, mountain ranges prevent a smooth transition inland from the coast. Some useful series of stations in long valleys leading away from the sea might perhaps be found; but since the larger valleys are more nearly parallel to the coast than normal to it, none gives a true transition inland. On the

[2] These figures are plotted from the means to 1930 published in the United States Weather Bureau's Climatic Summary of the United States, sections 33, 64, 65, and 85.

Gulf and Atlantic coasts the profiles are not disturbed by relief. I have examined several traverses inland from these coasts that yield profiles too irregular to be enlightening. It is evident that local peculiarities of exposure of instruments often obscure the smooth transition inland that is to be expected in areas of low relief. A more thorough search than I have made and a careful scrutiny of the data from many series of stations would probably yield useful profiles from areas not represented in Figures 3, 4, and 5.[3] Figures 3 and 5 sample the long stretch of Gulf and Atlantic

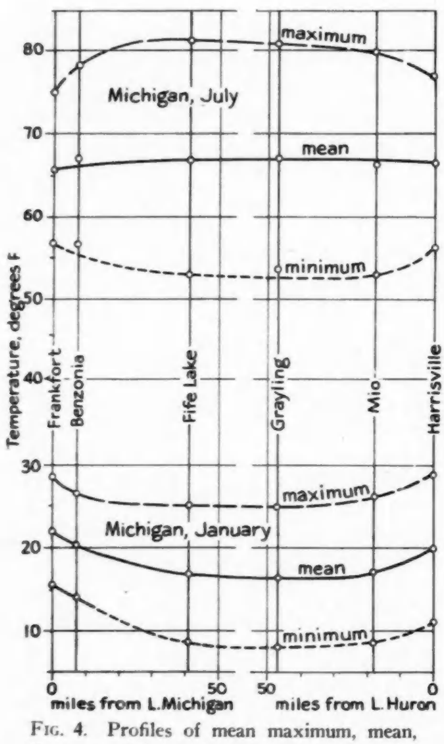

FIG. 4. Profiles of mean maximum, mean, and mean minimum temperatures across the Lower Peninsula of Michigan.

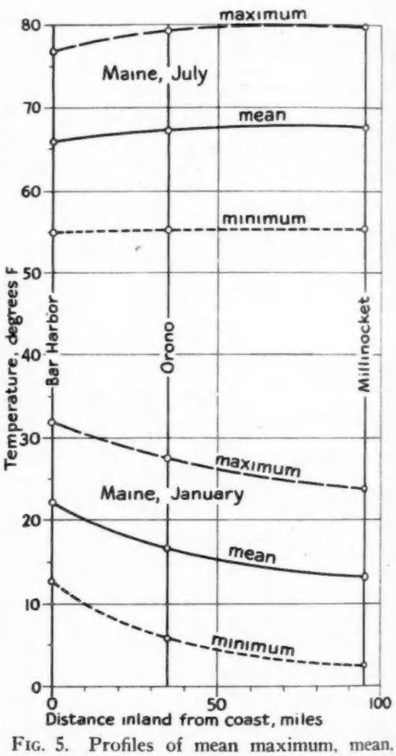

FIG. 5. Profiles of mean maximum, mean, and mean minimum temperatures inland from the Maine coast.

[3] Some palpable errors in the published data may be identified and corrected. The mean minimum January temperature at Galveston given in the Climatic Summary, for example, is nearly 4 degrees F. too low to yield, when combined with the accompanying mean maximum, the published mean monthly temperature. The value plotted in Figure 3 is the mean minimum that when so combined gives the published monthly mean. Such an error may be corrected where one of the three related means is inconsistent with the other two.

coast only at its extremities; they do not define the transition from one extreme region to the other. Instructive profiles other than the one reproduced in Figure 4 can undoubtedly also be drawn inland from the shores of the Great Lakes.

Texas. The profiles plotted in Figure 3 run north-northwestward from Galveston roughly parallel to the Brazos River. Temple, the station farthest inland, is more than 600 feet higher than Galveston, but no unmistakable effect of ascent of the land surface can be recognized in the data. In July the mean temperature rises only very slightly inland, but the mean maximum rises and the mean minimum falls rapidly immediately inland from the coast. The profiles for July are a close approximation to the schematic ones on Figure 2, *A*, though they indicate a stronger influence of onshore wind, in the manner illustrated in Figure 1, *B*, than do the curves in 2, *A*.

The January profiles in Figure 3 show only a slight fall in mean temperature in the first hundred miles inland. From this point on, increasing latitude and distance from the Gulf assert themselves in an increased slope of all three curves. The highest maximum evidently occurs some 50 miles inland. As is to be expected, the daily range is somewhat larger in summer than in winter, and there is a slightly greater reduction of range at the coast in January than in July. The average daily range at Galveston is only 35 to 40 per cent of the range at College Station in January and July respectively. Compared with the corresponding ratios in the profiles reproduced in Figures 4 and 5, these percentages reflect a strong maritime effect on the daily march of temperature at Galveston.

Michigan. In the vicinity of the Great Lakes, profiles can be drawn that are affected by the lakes at both ends. Figure 4 represents one such traverse, which spans the Lower Peninsula of Michigan north of Saginaw Bay from west to east near latitude 44° 40′ north. At Grayling the land surface is about 500 feet above the level of the lakes, but again no effect of elevation on the temperature profiles can be distinguished from the effects of continentality. Some minor irregularities in the July data were ignored in drawing the profiles, which are presented as smooth curves. In summer there is little difference in average temperature between the surfaces of the land and the lakes, but in winter the land is much colder than the lake surfaces. The sharp upturn of the January profiles at both ends as they approach the shores of the lakes indicates that at the coasts the air is on the average appreciably colder than over the lakes themselves.

The net movement of wind across Michigan is from west to east at all times of the year, but there is enough onshore wind from Lake Huron at both extreme seasons to produce a distinct maritime effect on the eastern parts of the profiles of both maximum and minimum temperatures. A measure of the dominance of west winds in the transport of heat between the lakes and the land can be gained by comparing the mean daily range at the stations at the ends of the profiles. In July the range at Frankfort is 88 per cent of the range at Harrisville, but in January it is only 74 per cent. Lake Huron evidently affects the daily range in eastern Michigan much more strongly in summer than in winter. The asymmetry of the circulation of air in

January manifests itself primarily in mean minimum temperature, which is higher by 4.5 degrees F. at Frankfort than at Harrisville.

Maine. The stations on the Maine profile, Figure 5, do not lie so nearly on a straight line as do the Texas and Michigan stations used in Figures 3 and 4. The abscissas of the stations in the figure were scaled off from the nearest points on a "coast line" lying about halfway between the headlands and the inner ends of the deep embayments of the coast, and so do not represent accurately the mutual distances among the stations. The profile is oriented nearly north-south, so that increasing latitude from the coast inland may reduce in summer and exaggerate in winter the difference in temperature between coast and interior that results from increasing continentality alone. The station at Millinocket is less than 400 feet higher than the one at Bar Harbor.

In comparison with the profiles in Figures 3 and 4, the onshore components of wind at Bar Harbor appear to exert little influence on the daily range of temperature at either extreme season. The mean daily range at Bar Harbor is 89 per cent of that at Millinocket in both January and July. Temperatures at Bar Harbor do not seem, however, to be truly representative of the Maine coast. In January the difference between the mean maximum and the mean minimum is 19.3 degrees F. at Bar Harbor, but only 15.2 degrees at Portland and 15.8 degrees at Eastport. The corresponding differences in July are 21.8, 16.0, and 16.8 degrees F. If the true daily range at the coast in the vicinity of Bar Harbor actually lies approximately halfway between the range at Portland and that at Eastport, the profiles in Figure 5 should resemble those for western Michigan. In the absence of further evidence, one would not venture to redraw the profiles with a smaller range at Bar Harbor than the published data give, but the representative character of those data may be doubted.

DISCUSSION

Two influences may be clearly recognized in the shapes of the profiles reproduced in Figures 3, 4, and 5: difference in mean daily temperature between the surfaces of land and water, and relative frequency of onshore and offshore winds. On the basis of the former factor, the profiles may be grouped as follows: 1. Large difference in temperature between land and water: western Michigan, eastern Michigan, and Maine, all in January. 2. Small difference in temperature between land and water: Texas in both January and July; western Michigan, eastern Michigan, and Maine in July.

In Group 1, the means of both extremes of air temperature display a strong maritime influence, and in western Michigan, where onshore winds predominate, proximity to the lake reduces the daily range perceptibly. As was noted above, the daily range at Bar Harbor plotted in Figure 5 is probably not representative. No effect of proximity to Lake Huron on the daily range is perceptible in the eastern part of the Michigan profiles. Because of their limited area, the Great Lakes can not be expected to exert so large a "maritime" effect as does the ocean, but this effect

should be easily recognizable. With the exception of the Maine profiles, the daily range is strongly reduced at the coast in Group 2. The reduction of range at the coast is rendered more conspicuous than in the profiles of Group 1 by the reversal of direction of the temperature gradient in the diurnal cycle.

Among the stations that appear in the profiles, Houston is the only one for which percentage frequency of surface winds from different directions is published.[4] Here there is a distinct predominance of onshore winds in July. In January, onshore and offshore winds are nearly equally frequent. The frequency of onshore winds in January is nevertheless sufficient to reduce conspicuously the daily range at Galveston. To judge from the scanty published information, onshore and offshore winds occur with nearly equal frequency in July, and west winds prevail in January, at the stations on both coasts of Michigan. South winds evidently prevail in July along the Maine coast, and offshore winds in January.[5]

Most of the peculiarities of the profiles in Figures 3, 4, and 5 result from the superposition in them of gradients that depend (1) on the diurnal and (2) on the annual march of temperature. Where, as on the Texas coast, the temperatures of land and water vary together in the annual cycle, so that the difference between them remains small, the transition within the daily cycle appears alone in the profiles drawn for both extreme seasons. In the absence of a seasonal temperature gradient in the coastal zone, the gradients of the daily extremes become conspicuous. The situation is favorable for the frequent alternation of land and sea breezes, which affect only a narrow belt of land. In the Michigan profiles, the annual swing in temperature brings land and lake surfaces to nearly the same mean temperatures in summer. Temperature profiles at this season therefore resemble those drawn from the Texas data. The western parts of the Michigan profiles for January exhibit a distinct maritime influence in both the daily and the annual march. There is a steep temperature gradient inland at both the maximum and the minimum. At the same time the daily range is reduced at the coast. The seasonal change in temperature gradient extends farther inland than does the diurnal change. Such a combination of effects is to be expected from general considerations of heat transfer from water to circulating air when the water is warmer than the adjacent land and onshore winds predominate.

January profiles from eastern Michigan do not fulfill this expectation. There is a steep temperature gradient inland, but no noticeable reduction in daily range near the coast. It is obviously the advection of air from over the water that raises the general level of temperature in the coastal zone; why, it may be asked, does it not

[4] In the form of surface wind roses: United States Weather Bureau, Airway Meteorological Atlas for the United States (New Orleans, 1941), charts 3 and 9.

[5] According to the Climatic Summary cited in footnote 2, the prevailing wind in July at Alpena, some 30 miles north of Harrisville, is southeast. At Ludington, about the same distance south of Frankfort, it is south. At Portland and Eastport, Maine, south winds prevail in July and northwest and west winds in January.

also reduce the daily range as it does on the western, windward coast of the peninsula? Why, in other words, do not the "maritime" effects on both the seasonal and diurnal gradients inland vary together, since both depend on the same movements of air from water to land? Why does the "maritime" effect on daily range become imperceptible in the January profiles while the seasonal temperature gradient inland still remains steep? The following considerations may point toward an answer:

The large difference in mean temperature between land and water precludes a daily alternation of land and sea breezes. Onshore winds occur as parts of the circulations about migrating cyclones and anticyclones. They thus transport large volumes of air from water to land and affect a wide zone inland. During the time when these winds are blowing, the coast must share in the limited daily range that prevails over the water. Once onshore, however, the air is subject to the normal thermal régime of the land. The continental daily march of temperature is established in it before its mean temperature has approached equilibrium with the land surface. The large daily temperature fluctuation characteristic of the land thus proceeds, in the course of continental modification of maritime air, at a mean temperature higher than that which obtains in true continental air in winter. The mean temperatures by which the steep gradient inland is defined include individual observations of relatively high temperature in maritime air. But many of these observations are made after the onshore movement of air has ceased, and while this air, still warmer than true continental air, is drifting eastward again as offshore wind. Much of the offshore wind recorded does not consist of continental air, but of modified maritime air returning from over the land. In this air the daily range of temperature is of continental magnitude, but its mean daily temperature is higher than that of true continental air. A slight reduction of the daily range should be observed near the coast. That none appears in the January profiles of eastern Michigan may reflect deficiencies in the observations.

Figures 3, 4, and 5 sample only a limited number of possible combinations of temperature difference between adjacent land and water and wind movement; other combinations probably exist. These profiles do raise questions, however, concerning the interchange of heat between circulating air and surfaces of land and sea, and suggest answers to them. Examination of other profiles should yield further insight into this important climatic process.

CLIMATE AND MOISTURE CONSERVATION

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RELATIONSHIPS BETWEEN RAINFALL AND EVAPOTRANSPIRATION

PART of the moisture that is stored in the soil during rains evaporates directly back to the air from the soil surface and part is available to plants. Most of the water that enters a plant through its roots is later transpired from its leaves and stems. The combined evaporation from the soil surface and transpiration from plants, called evapotranspiration, represents the return flow of water from the earth to the atmosphere and is the opposite of precipitation. The amount of water in the root zone of the soil available to plants depends on the relation between precipitation, which adds water, and evapotranspiration, which removes it. Since rainfall and evapotranspiration are due to different things, they are not often the same either in amount or in distribution through the year. In some places more rain falls month after month than the vegetation can use. The surplus moves through the ground and over it to form streams and rivers and flows back to the sea. In others, month after month, there is less water in the soil than the vegetation could use if it were available. There is no excess of rainfall and no runoff, except locally where the soil cannot absorb all the water as it falls. Consequently, there are no permanent rivers and there is no drainage to the ocean. In still other areas the rainfall is deficient in one season and excessive in another, so that a period of drought is followed by one with runoff. The march of precipitation through the year never coincides exactly with the changing demands for water in any part of the world.[1]

TYPES OF DROUGHTS

Drought is the greatest natural hazard to agriculture. Everyone knows that drought makes farming difficult or impossible in the semiarid and arid regions of the earth. But few realize that even in the humid and subhumid regions, such as eastern United States and western Europe, droughts are frequent and severe. They are chiefly to blame for low average yields. They are also the cause of occasional crop failures. But drought cuts quality as well. Foods that have suffered from drought are neither so good nor so nutritious as those that have not. The dreaded famines of India and China are a direct result of drought. Drought is widespread in nearly every part of the world.

[1] Thornthwaite, C. W., "The moisture factor in climate," *Trans. Amer. Geophys. Union*, Vol. 27 (1946), pp. 41–48.

There are three different kinds of drought. The first, which we may call permanent drought, is characteristic of the driest climates. The sparse vegetation is adapted to drought, and agriculture is impossible except by irrigating through the entire crop season. The second, or seasonal drought, is found in the climates that have well-defined rainy and dry seasons. The natural vegetation is made up of plants that produce seeds during the rainy season and then die, and of plants that remain alive but become dormant in the dry season. For successful agriculture, planting-dates must be adjusted so that the crop develops during the rainy season. Otherwise, crops must be irrigated during the dry season. The third kind of drought results from the fact that rainfall is irregular and variable everywhere. These droughts depend upon the irregularity of rainfall and thus are not certain to occur in any definite season, but they are most probable at the time of maximum water need. We may call them contingent droughts. They may occur almost anywhere, even in the areas of seasonal drought, but are most characteristic of subhumid and humid climates. They are usually brief and irregular and may affect a relatively small area. They are the most treacherous because they vary greatly in intensity and time of occurrence and are thus seldom anticipated.

DEFINITIONS OF DROUGHT

Drought is most accurately described as a condition in which the amount of water needed for transpiration and direct evaporation exceeds the amount available in the soil. It results from too little rain. Soil moisture is used up, and plants then suffer from lack of water. So long as the soil lacks moisture, rain water cannot pass through the root zone to replenish ground water. Ground-water supplies will finally fail, and streams will dry up. Only when the rainfall is greater than the water need is there a surplus of water to build up either soil moisture or ground water, and to start streams flowing again. The various aspects of drought are thus interrelated, and there is no need to distinguish between climatic, biologic, or hydrologic drought.

Because it is so hard to determine water needs, we find drought usually defined as a period of consecutive days without rainfall. According to Henry, of the United States Weather Bureau, a drought exists "whenever the rainfall for a period of 21 days or longer, is but 30 per cent of the average for the time and place."[2] The meteorologists of the Tennessee Valley Authority say that drought is a period of time within which no interval of 21 consecutive days received an amount of precipitation greater than one-third of normal.[3] The British Rainfall Organization defines an "absolute drought" as a "period of at least 15 consecutive days, to none of which is credited .01 inch of rain or more."[4] Other attempts to define drought restrict the

[2] Henry, Alfred J., "The great drought of 1930 in the United States," *U. S. Monthly Weather Rev.*, Vol. 58 (1930), pp. 351–54.

[3] Tennessee Valley Authority, Hydraulic Data Division, Precipitation in Tennessee River Basin, August, 1944.

[4] *British Rainfall, 1935.* Air Ministry Meteor. Office, London, 1936.

rainfall to a definite percentage of the monthly or annual normal value. One such definition states that drought occurs when the annual precipitation is 75 per cent of normal or when monthly precipitation is 60 per cent of normal.[5] Another says that any amount of rainfall less than 85 per cent of normal constitutes drought.[6]

It is evident that we cannot define drought as a shortage in rainfall alone. Such a definition would fail to take into account the amount of water needed. Furthermore, the effect of a shortage of rainfall depends on whether the soil is moist or dry at the beginning of the period. Shantz[7] explained that drought in its proper sense is related to soil moisture and that it begins when the available soil moisture is diminished so that the vegetation can no longer absorb water from the soil rapidly enough to replace that lost to the air by transpiration. Drought does not begin when rain ceases but rather only when plant roots can no longer obtain soil moisture. As early as 1906, Henry pointed out that the intensity of drought could not be measured as a departure of rainfall from the normal, "since a deficiency of 50 per cent in a region of abundant rainfall is not so serious as the same deficit in a region where the average precipitation is barely sufficient for the needs of staple crops."[8]

COMPARISON OF RAINFALL AND WATER NEED IN COLUMBIA, SOUTH CAROLINA

Let us suppose that the rainfall and the water needed by plants at a place in southeastern United States vary through the year as shown in Figure 1. Only a little more than a half-inch of water is needed in each of the winter months. The need rises rapidly during the spring and reaches a high point of nearly 7 inches in July. It falls rapidly during the autumn months. Between 3 and 4 inches of rain falls in each of the six winter and spring months. The largest amounts of rainfall, nearly 6 inches, come in July and August. In the driest months, October and November, only a little more than 2 inches of rain falls.

In this example, rainfall and water need do not coincide. There is too much rain in winter and too little in summer. In midautumn, water need falls below precipitation. For a while the surplus rainfall replaces soil moisture that had been used up previously. From then on the surplus water raises ground-water levels and produces surface and subsurface runoff. But it is of no benefit to plants. In spring both transpiration and evaporation increase rapidly and soon water need surpasses precipitation. Thereafter until midsummer the excess demands for water are satisfied by the soil moisture reserves. When these reserves are exhausted the plants must rely solely on current rainfall.

[5] Bates, C. G., *Climatic characteristics of the Plains Region;* in M. Silcox, F.A., *et al.*, *Possibilities of shelterbelt planting in the Plains Region*, Washington, 1935.

[6] Hoyt, John C., Droughts of 1930–34, *U. S. Geol. Survey Water Supply Paper 680*, 1936.

[7] Shantz, H. L., "Drought resistance and soil moisture," *Ecology*, Vol. 8 (1927), pp. 145–57.

[8] Henry, Alfred J., *Climatology in the United States*, U. S. Weather Bur. Bul. Q, 1906.

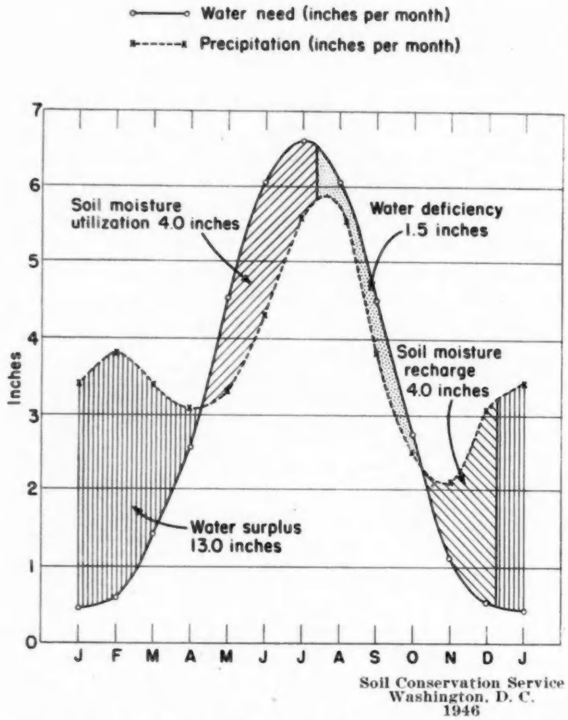

FIG. 1. Relation of precipitation to water need in Columbia, S. C.

POSSIBLE COUNTERMEASURES

There are several things that can be done to bring water need and rainfall more nearly together. Since it is impossible to change the rainfall to fit the water need, changes must be made in other ways. One possibility is to increase the storage capacity of the soil for moisture. Every added inch of usable water in the soil is as good as an extra inch of rainfall and will delay the onset of drought for a certain length of time. Unfortunately, many farming practices reduce the storage capacity of the soil rather than increase it. Crop rotations, with the frequent use of grasses and legumes, improve the soil structure and increase its water storage capacity. So does lime applied as needed. Furthermore, these practices make the soil more absorptive, and less water is lost by direct runoff when the rains are intense.

A second possibility is to reduce the water needs of the crop. Plants that use less water or farming practices that increase the efficiency of water use could minimize drought.

A third possibility where the time of drought can be anticipated is to readjust the crop calendar so that the harvest will come before the drought is likely to become too great. This might mean earlier planting. And earlier planting might, as in the example of Figure 1, require land drainage to dispose of excess water and to allow proper aeration. When we know how serious drought may be and when to expect it, we may examine all farming operations and develop cropping schedules to evade it.

A fourth possibility is to make up the water deficiency by use of supplementary irrigation, to be considered later.

UNKNOWNS IN MOISTURE CONSERVATION

Scientists have much to do before we shall know how to correct the defects of bad rainfall distribution. We still do not know which method is most desirable at any time or place. We need to know how great the drought is and when it comes. To do this we must determine not only the rainfall, but the water need as well. We know reasonably well how rainfall varies from one place to another over the inhabited parts of the earth. We also know how it varies through the year and from one year to another. On the other hand, we know very little about water need. We shall be able to measure actual evapotranspiration as soon as proper methods are developed. But potential evapotranspiration, the amount of water that would be evaporated and transpired if it were available, we cannot measure directly. This is the water need. It must be determined by experimentation, and in other ways.

We have been aware for a long time of the need for means to determine evapotranspiration. The fact that we cannot yet measure it accurately simply means that it is hard to measure and that we have not spent enough effort in working out instruments and methods. At least we know how it can be measured.[9]

Since potential evapotranspiration is an important climatic element we need to know its distribution over the earth and how it varies through the year and from one year to another. Actual determinations are so few that it would be impossible to make a map of any area by means of them. So long as direct methods for determining potential evapotranspiration remain undeveloped, the only alternative is to discover a mathematical relation to other climatic factors of which there are abundant data.

The fact that potential evapotranspiration or water need is high in the southern part of the United States and low in the northern part, and the fact that it varies greatly from winter to summer, show that it is directly related to temperature. From

[9] Thornthwaite, C. W., "The measurement of evaporation and transpiration from natural surfaces," *Proc. Hydrologic Conference (Pa.)*, No. 27 (1941), pp. 185–97. Thornthwaite, C. W., "Atmospheric Turbulence and the Measurement of Evaporation," *Proc. Second Hydraulic Conference, Bul. 27*, Iowa Studies in Engineering, 1943. Thornthwaite, C. W. and Holzman, Benjamin, "Measurement of evaporation from land and water surfaces," *U. S. Dept. Agri. Tech. Bul. 817*, 1942. Thornthwaite, C. W., Wilm, H. G., *et al.*, "Report of the committee on transpiration, 1943–44," *Trans. Amer. Geophys. Union for 1944*, Part V, pp. 683–93.

various observations made in irrigation projects in the West and on watersheds in the East, it has been determined that there is a close relation between mean monthly temperature and water need, when adjustments are made for variation in day length. Using the available observations it has been possible to develop a formula that describes the relation between temperature and water need. This formula permits the computation of water need for any place whose latitude is known and for which temperature records are available.[10] We can test the accuracy of these computations in a number of ways. They are of the right order of magnitude throughout most of the United States. We must realize, though, that they are only approximate. More exact determinations must await further study.

The average annual water need in the United States ranges from less than 18 inches in the high mountains of the West to more than 48 inches in the South. It is less than 21 inches along the Canadian border. Curves showing the march of water need and rainfall at a number of selected stations in the United States are given in Figures 2–4. Figure 1, for Columbia, South Carolina, is representative of a large part of southeastern United States. From these graphs we can readily tell when rainfall is likely to be excessive and when deficient.

Except in equatorial climates, water need varies systematically from month to month throughout the year; it is small in winter and, even in the polar regions, large in summer. Its march through the year follows a uniform pattern in most of the United States. In the winter months it is negligible as far south as the Gulf Coastal Plain; it is only 2 inches per month in southern Florida. It rises to a maximum in July that ranges from 5 inches along the Canadian border to 7 inches on the Gulf coast. In some mountain areas and along the Pacific coast it does not reach 5 inches in any month.

The march of precipitation is highly variable from one region to another. In much of the United States more than half of the rain falls during the growing season. In the Pacific Coast States the distribution is reversed; most of the rain falls in winter at the time of lowest need. In large areas in eastern and southeastern United States, the rainfall does not vary much from month to month except for a slight drop in autumn.

Drought does not begin immediately when rainfall drops below the water need. Moisture that accumulates in the soil at times of rainfall excess and is within reach of roots is used before the plants begin to suffer. The amount of water in the root zone available to plants varies with the soil structure and with the distribution of roots from a mean that is about equal to 4 inches of rainfall.

[10] The formula is described in detail and methods for its use outlined in "An Approach Toward a Rational Classification of Climate," to be published in the *Geographical Review*. A map of average annual potential evapotranspiration in the United States is included.

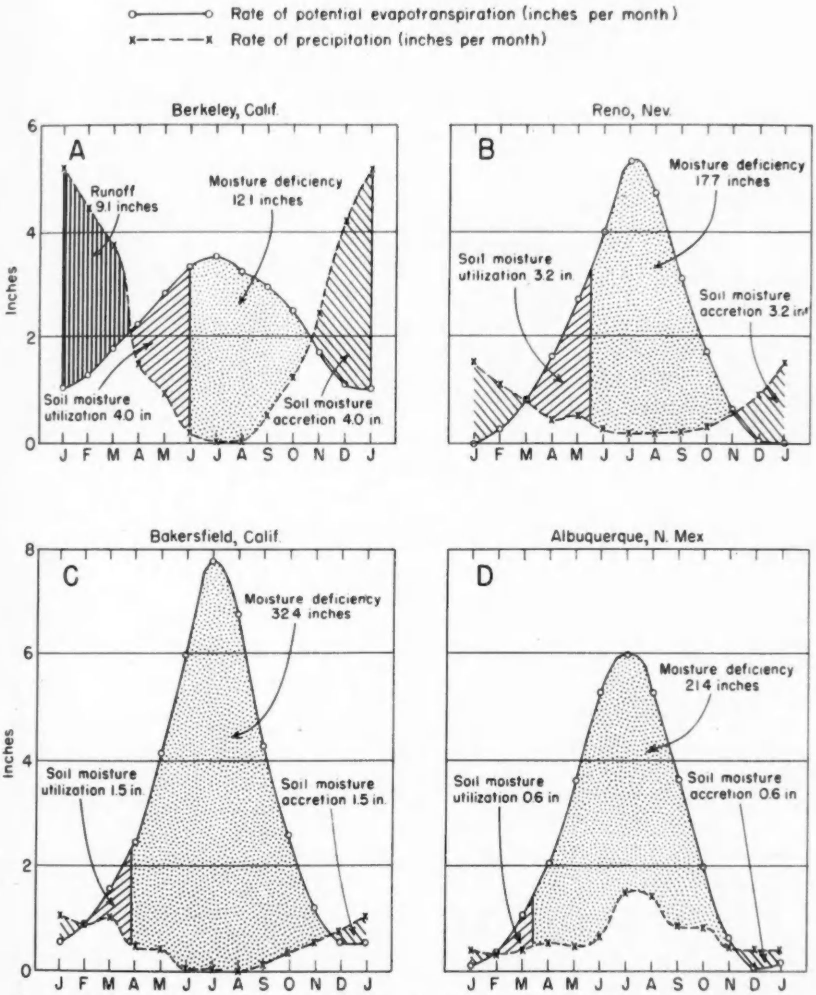

FIG. 2. Relation of precipitation to water need at representative stations: Berkeley, Calif.; Reno, Nev.; Bakersfield, Calif.; and Albuquerque, N. M.

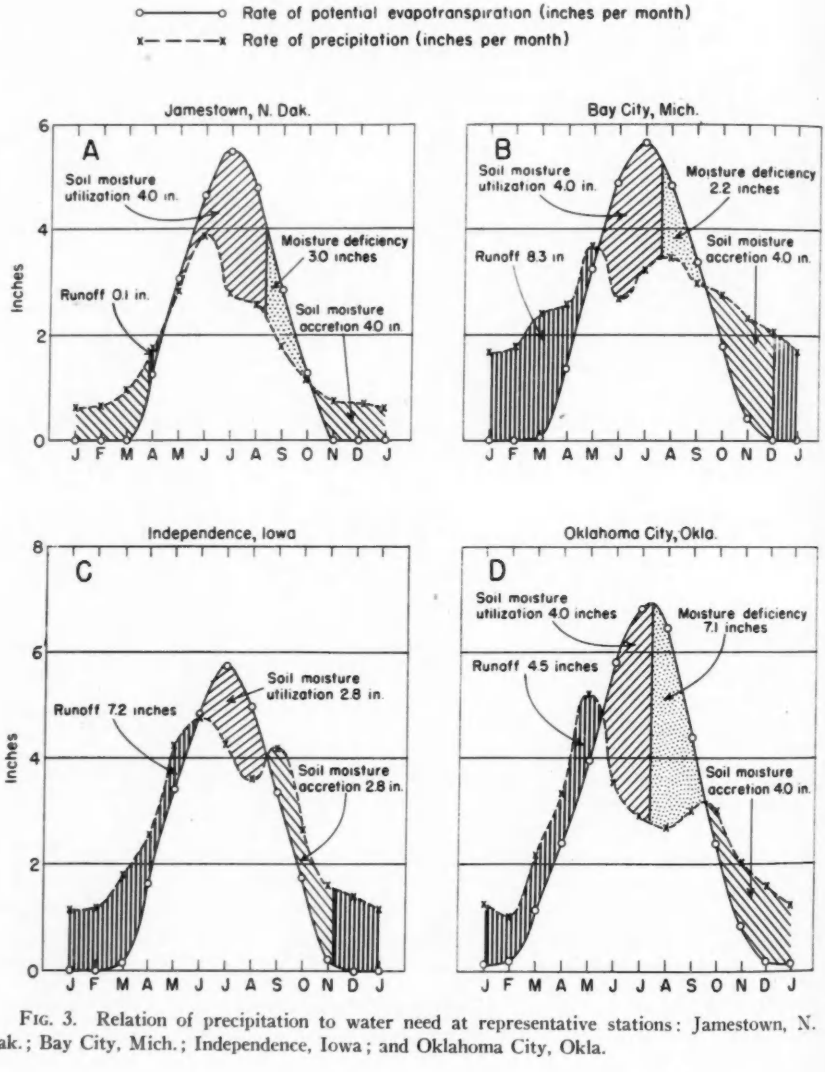

FIG. 3. Relation of precipitation to water need at representative stations: Jamestown, N. Dak.; Bay City, Mich.; Independence, Iowa; and Oklahoma City, Okla.

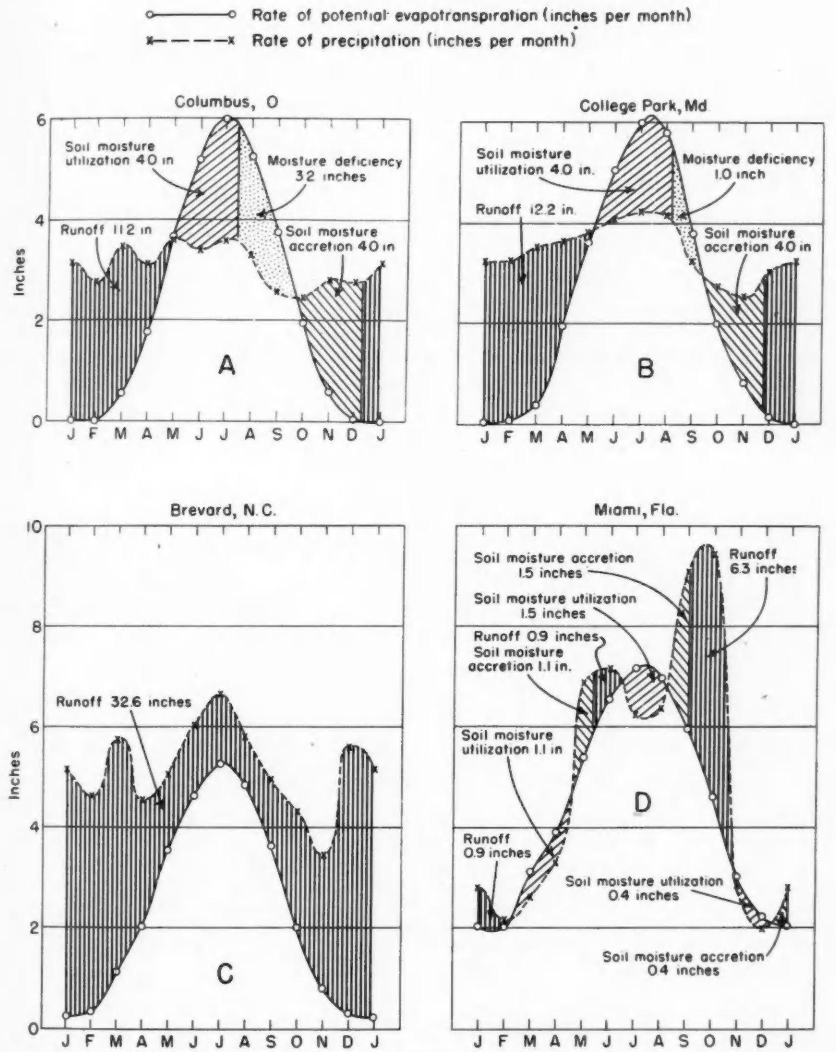

FIG. 4. Relation of precipitation to water need at representative stations: Columbus, Ohio; College Park, Md.; Brevard, N. C.; and Miami, Fla.

MOISTURE DEFICIENCIES AND SURPLUSES

In Reno, Nevada, Bakersfield, California, and Albuquerque, New Mexico (Fig. 2), water need is so much greater than rainfall that no form of moisture conservation can make agriculture possible. Irrigation is an absolute necessity. In Berkeley, California (Fig. 2), the rainfall nearly equals the need, but it is so badly distributed through the year that a lot of water is lost during the winter and there is a large moisture deficiency in summer. Here summer crops are possible only with irrigation. But the crop calendar can be readjusted to take advantage of the winter rains, by growing crops that are planted in the autumn. At the four places shown in Figure 3 and at Columbus, Ohio, and College Park, Maryland (Fig. 4), all of the measures for conserving moisture or increasing the efficiency of its use may be employed effectively. In all of them supplemental irrigation would materially increase crop yields in some years. In Brevard, North Carolina (Fig. 4), there is a surplus of rainfall in every month; the total rainfall is more than twice the need. Good agricultural practice here will involve land drainage. Drainage of the winter water surplus would be necessary also in Bay City, Michigan (Fig. 3), Columbus, Ohio, and College Park, Maryland (Fig. 4), if farmers are to begin planting early in the spring. The large rainfall excess in the autumn in Miami is due to the tropical cyclones that occur regularly in that season.

Both rainfall and water need vary from one year to another. Thus, because they are made from averages, the curves in Figures 2, 3, and 4 tell only a partial story. Even a place like Brevard, North Carolina (Fig. 4), may occasionally experience drought. Although no moisture deficiency is shown for Independence, Iowa (Fig. 3), there actually are short droughts in most years. In order to determine how severe drought may be in a place, we must compare water need with water supply in individual years. In this way we can determine how often water deficiencies of various amounts take place. Figure 5 shows the water deficiencies during the 25-year period 1920–1944, at four stations in agricultural areas of the United States. Comparative moisture data of these four stations are given in Table 1.

TABLE I

COMPARATIVE MOISTURE DATA OF SELECTED STATIONS
(Median values of 25-year period 1920–44)

Station	Potential evapo-transpiration	Precipi-tation	Actual evapo-transpiration	Water surplus	Water deficiency
	Inches	*Inches*	*Inches*	*Inches*	*Inches*
Hays, Kansas	31.26	22.13	21.02	0.00	11.30
Charles City, Iowa	25.91	30.94	23.19	8.90	2.72
Wooster, Ohio . . .	26.46	35.63	23.82	11.26	2.91
Auburn, Ala.	39.45	49.84	33.07	18.43	6.73

In the above table, the stations are arranged in order of increasing rainfall. In Hays, Kansas, the least rainy station, the rainfall of half of the years is less than 22 inches; in Auburn, Alabama, the rainiest, it is more than 50 inches. In Hays the median rainfall is about 10 inches less than the need, whereas in Auburn it is 10 inches greater. In Auburn, however, much of the rainfall comes at a time when it is not needed. It becomes surplus water and flows uselessly away. The maximum annual surplus is as much as 40 inches and is more than 20 inches nearly half of the time. Thus in Auburn water deficiency is large. The maximum deficiency is more than 16 inches; in 20 per cent of the years the deficiency is more than 10 inches; and in 80 per cent it is more than 5 inches. Water deficiency is likewise large in Hays, ranging from nearly 20 inches to about 2 inches. In Hays there is not enough rainfall; in Auburn there is more than enough but it is badly distributed through the year.

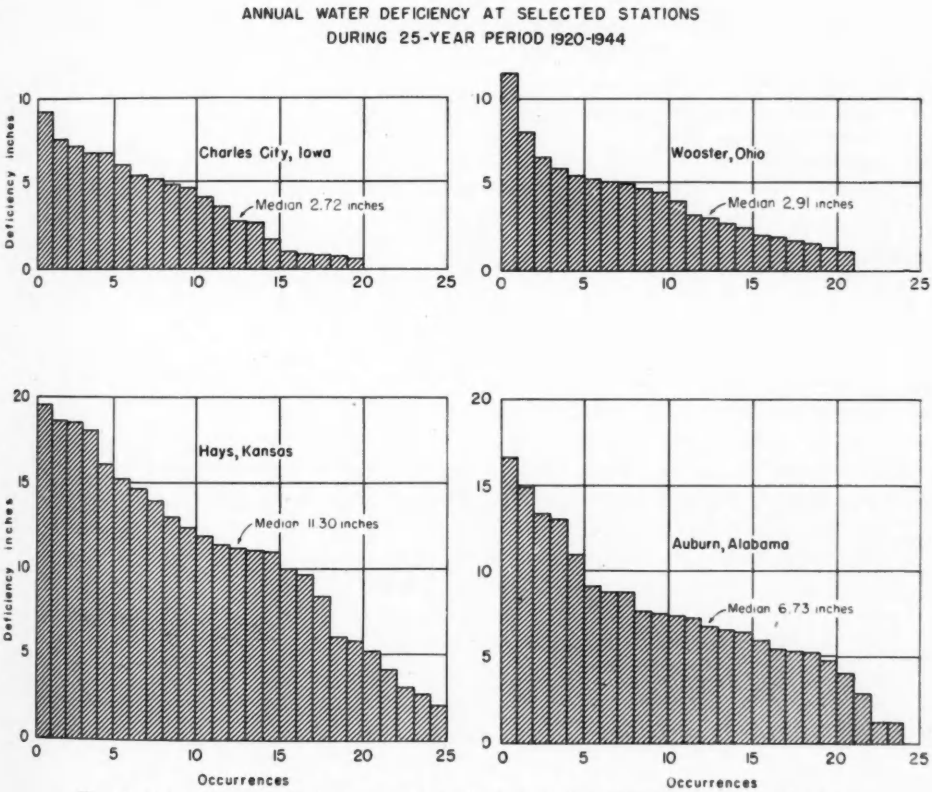

FIG. 5. Annual water deficiency during the 25-year period, 1920–1944, at selected stations: Charles City, Iowa; Wooster, Ohio; Hays, Kans.; and Auburn, Ala.

In both Charles City, Iowa, and Wooster, Ohio, water deficiency is less than 5 inches in 70 per cent of the years and less than 3 inches in half of the years. In Charles City it is less than 1 inch in 40 per cent of the years. Drought intensity and frequency are a little smaller in Charles City than in Wooster. There is also less surplus water in Charles City; 8.90 inches compared with 11.26 inches. Thus, of the four stations, Charles City most nearly approaches the ideal climate for agriculture, for its water supply most nearly coincides with water need.

IRRIGATION IN COMBATING DROUGHT

Of the various means considered for combating drought, irrigation is the only one that we can modify to meet the varying conditions of individual years. Thus, irrigation should be considered for use not only in arid and semiarid climates but in any place where drought cuts agricultural production.

One of the earliest books on irrigation in the United States, published in 1877, dealt with the need for this practice in the eastern part of the country. The author wrote:

> Farmers and gardeners in the East, who for some years past, for want of rain, have seen the profit of their labor lost, are seeking some cheap and effective methods of irrigation, by which such calamity may be avoided in the future. . . . The American climate is especially subject to destructive drought, and scarcely a year passes in which the crops do not partially or wholly fail over extensive districts. . . . The farmer, when rain fails, is helpless, yet there may be abundant water flowing uselessly past his suffering crops. . . . But it is not only a question whether or not crops can be produced where they are now impossible, or whether or not the effects of drought may be averted by irrigation, but whether or not the general average of the crops may be largely increased by the systematic use of partial irrigation, and the use of such supplies of water as a majority of farmers can readily avail themselves of.[11]

The first irrigation investigations conducted by the Department of Agriculture more than 50 years ago dealt with irrigation in the humid eastern part of the country.[12] Nevertheless, we have almost no irrigation east of the 100th meridian except of rice and citrus fruits. The Federal Census of 1940 reported 36,000 acres under irrigation on 3,600 farms east of the Mississippi River, an average of 10 acres per farm. Not one farmer in 12,000 could supply water to crops in time of drought.

So slight is the interest in irrigation in the Eastern states that almost no body of law governing water rights has been developed. Practices depend principally upon court decisions, in which the courts have been guided largely by English common law. Riparian doctrine governs the use of water flowing in surface streams or in underground streams, but percolating ground water is the property of the land owner. In most of the East, water is so abundant that there are at present no effective legal restrictions to its use in irrigation. The law has not inhibited the growth of irrigation.[13]

[11] Stewart, Henry, *Irrigation for the farm, garden, and orchard,* Orange Judd Co., New York, 1877.

[12] U. S. Dept. Agr., *Report* of the Secretary of Agriculture, 1893, p. 434.

[13] Hutchins, Wells A., "Water rights for irrigation in humid areas," *Agr. Engineering,* Vol. 20 (1939), No. 11, p. 431.

Interest in irrigation in Eastern United States is slight because farmers have not recognized the need for it. Droughts are seldom so severe as to result in complete crop failure, and the reduced yields resulting from drought are accepted as a natural feature of the region. On the other hand, farmers have not realized full benefits in increased crop yields where they have tried irrigation. They have not known how much or when water was needed. Often they have supplied too little water to the crops or supplied it too late. Sometimes they have used it too lavishly. The evil of too much water was emphasized more than 70 years ago. "The absolute necessity of water to vegetable growth must not be accepted in an unqualified sense. Water is a good and necessary thing, but there may be too much of it, and too much is as fatal to the profitable culture of land as too little."[14]

The various experiments on supplemental irrigation in Eastern United States have done little to determine how much and when to apply water. Even today in Western United States, where irrigation is vital to agriculture, there is little real knowledge of the true needs of crops for water. Thus, the thing we need most to know in irrigation farming is how much water is needed, and when.

IRRIGATION PRACTICES NEED IMPROVEMENT

Common irrigation practice is to watch the plants for signs of moisture deficiency as a basis for supplying water. Fruit growers, for example, may keep records of the rate of growth of the fruit so as to add water when growth stops or is seriously retarded. M. R. Lewis said in 1943: "An experienced farmer can tell when his crops are suffering badly for water. The trick is to tell a few days before they start to suffer and apply water soon enough to prevent any set-back. . . . The most common mistake is to wait too long before starting to irrigate. Any serious set-back of the crop from lack of moisture means a correspondingly reduced yield at harvest."[15]

The bad effect of lack of moisture on quality and yield persists through the entire growing season. The notion is widespread that cotton, for example, needs drought to induce it to pass from the vegetative to the reproductive stage. Experiments in California have shown the contrary. Withholding water near the end of the growing season caused an excessive shedding of bolls and squares, and a lack of water at any time caused a reduction of plant height, vigor, and final yield. Keeping the crop supplied with the optimum amount of soil moisture for growth may have a bad indirect effect on the final yield of the crop; for example, by an increase of insect pests and plant diseases, or of the tendency of small grains to lodge. These external unfavorable conditions should be controlled in other ways, not by depriving the crop of needed moisture. Here the agriculturist should seek the counsel and assistance of the entomologist, the plant pathologist, and the plant breeder.

[14] Stewart, Henry, *Irrigation for the farm, garden, and orchard*, Orange Judd Co., New York, 1877, p. 145.

[15] Lewis, M. R., "Practical irrigation," *U. S. Dept. Agri. Farmers' Bul.* No. 1922, published in 1943.

If the farmer proposes to supply supplementary water to the crop when it is needed, he must have some practical means of determining how much water to use and when to use it. Scientists have developed instruments to find out how much water the soil contains. Unfortunately, they do not yet provide the farmer with a practical means of knowing when the soil has reached a dangerous stage of dryness. Evaporation and transpiration deplete soil moisture and rainfall restores it. Thus if he knew the daily water needs of the crop and the daily rainfall, it would be a simple matter to determine day by day the extent to which the moisture reserve in the soil is being depleted. Since the water-needs during a day depend mainly on the temperature and the length of day, we can compute the available moisture in the root zone by the method already described. Of course, the stage of development of the crop must be considered; a newly seeded field loses water for a time only by surface evaporation.

Where a close-growing crop of perennials such as alfalfa or grass is involved, water-needs not satisfied by rainfall can be determined quite accurately by computation. For example, in order to prevent available soil moisture from falling more than 2 inches below a full supply at College Park, Maryland, supplementary irrigation would have been needed as follows:

Year	*Number of 2-inch applications*	*Year*	*Number of 2-inch applications*	*Year*	*Number of 2-inch applications*
1932	6	1937	3	1942	4
1933	4	1938	5	1943	7
1934	5	1939	8	1944	7
1935	5	1940	6	1945	3
1936	7	1941	8		

During 8 years at Ithaca, New York, the annual water deficiency ranged between 4 and 12 inches; the average was 9.25 inches. During 13 years at Lake City, Michigan, the range was also between 4 and 12 inches, but the average annual water deficiency was only 7.38 inches.[16]

Differences in average yield of different localities are proportional to differences in drought incidence. The farmers of the East and Southeast get low returns from their work on the land partly because of high drought incidence resulting from the lack of coincidence between rainfall and water need. During much of the growing season the soil does not contain enough moisture, and in the non-growing season a large water surplus impoverishes the soil by leaching.

To farmers everywhere drought is a serious matter. Drought is hard to measure because we are not yet able to determine the water needs of plants very accurately. We do not know when to expect droughts or how intense they may be. Therefore, we cannot be sure which moisture-conservation measures may be best at a given time and place. Droughts deserve real study. Only when we have learned how to measure evapotranspiration, both potential and actual, shall we be able to combat drought intelligently.

[16] Further discussion of this method of following the changes in available soil moisture from day to day through the year will be found in: Thornthwaite, C. Warren, "El agua en la agricultura" (Ciclo de conferencias dictadas por el autor, los dias 20 y 21 de Septiembre de 1945), *Irrigación en Mexico,* Abril–Mayo–Junio–1946.

THE CARTOGRAPHY OF JAPAN DURING THE MIDDLE TOKUGAWA ERA: A STUDY IN CROSS-CULTURAL INFLUENCES

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University of Michigan

AFTER nearly a century of extensive communication with foreign lands and peoples, Japan, under the third Tokugawa shogun, Iyemitsu, closed its doors to aliens. The edicts issued by the Tokugawa government between 1636 and 1641 prohibited all Japanese traffic with the outside world, and restricted Japan's foreign intercourse to the small Dutch settlement on Deshima Island, in Nagasaki Bay, and to a few Chinese ships visiting that port. For over 200 years thereafter Japan remained a closed country, and the cartographer intent upon mapping the North Pacific had to rely on sporadic, isolated, and often unreliable sources of information.

There is but little doubt that the mapmakers of Japan, for some decades prior to the edicts of exclusion, relied rather heavily on Western sources. We have documentary evidence, in the form of surviving Japanese charts and maps, of the extent of Western, especially Portuguese, influence on the construction of Japanese charts, during the latter part of the 16th and the early part of the 17th century. The coastal survey of the Spaniard Vizcaino, made in 1611, was reflected in some Japanese maps, and large-scale maps of the islands were compiled by Japanese draftsmen during the Keichō (1596–1615), Shōhō (1644–1648), and later, the Genroku (1688–1704) eras.[1] From the very beginning of their trade with Japan, the Dutch, leading cartographers of Europe during the late 16th and most of the 17th century, shipped a large number of their charts, maps, atlases, and globes to Japan, for the use of the feudal lords and of the Yedō government.[2] Little attention seems to have been paid to the reverse side of the medal, however, and most students of the early cartography of the Pacific seem to have neglected the influence of Japanese maps on Western attempts to depict the island world of Japan.

[1] Cf. Boxer, C. R.: *Jan Compagnie in Japan: 1600–1817. An essay on the cultural, artistic and scientific influence exercised by the Hollanders in Japan from the 17th to the 19th centuries;* The Hague, 1936; p. 15.

[2] *Ibid.*, p. 11–12.

All of the maps reproduced here in facsimile are from the collection of the William L. Clements Library of the University of Michigan. The author wishes to express his appreciation of the help extended by Dr. Randolph G. Adams, Director of the library. Dr. Joseph K. Yamagiwa was most helpful in translating the Japanese text of the manuscript map shown as Fig. 10.

In 1715, or thereabouts, the Ottens brothers, mapmakers in Amsterdam, published a map of the Japanese Empire, compiled by Adrien Reland, a linguist and historian, and professor of philosophy and Oriental languages at the University of Utrecht (Fig. 1). Reland was primarily a Semitic scholar, but he was also familiar

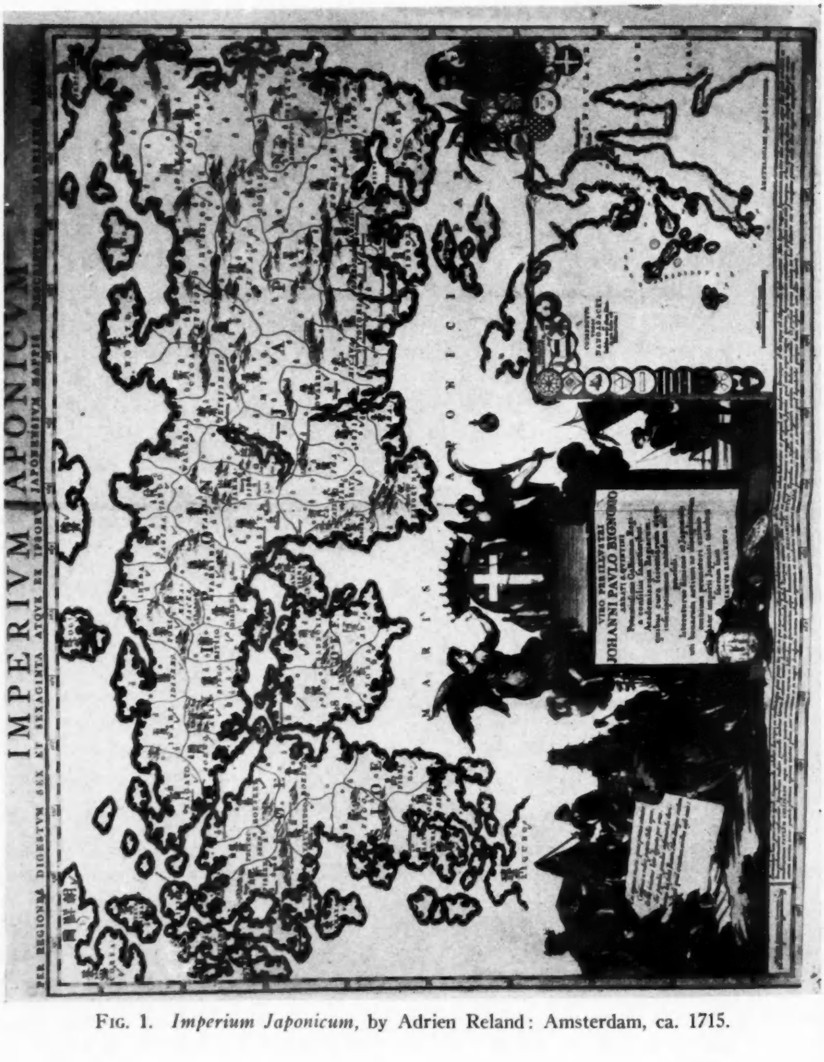

FIG. 1. *Imperium Japonicum,* by Adrien Reland: Amsterdam, ca. 1715.

with other Oriental tongues and conversant with the Persian, Syriac, Chaldaean, and Malay languages, besides Hebrew and Arabic. The greater part of his work was concerned with the Semitic languages and civilizations, but he also dabbled in cartography and compiled, besides this map of Japan, maps of Persia and Palestine. At first glance, his map does not reveal any unusual characteristics, except in one respect: the delineation of the sixty-six feudal divisions, the "Kuni," of Tokugawa Japan. Their names, printed in Japanese characters, are transliterated in the Dutch manner. Reland himself indicates, in a long marginal note, that the inset on his map, showing Nagasaki harbor, is based on what was probably a manuscript sketch, made by one of his countrymen, and showing all details of the coastline of southwestern Japan from Hirado, the old settlement of the Dutch, to Nagasaki, their factory in Japan at the time of the publication of the map. He also states that the feudal provinces shown on this map are based on a Japanese map communicated to him and found in the library of a former Director of the Dutch East India Company, Benjamin Dutry.[3]

Since the Dutch factory at Nagasaki sent back regular and detailed reports on happenings inside Japan, the appearance of some cartographic information based on Japanese sources does not seem surprising. It is only when we compare Reland's map with other, contemporary maps of Japan that certain important differences appear. Coronelli's map of Japan, published in 1696 (Fig. 2), for instance, while not as detailed as Reland's—it does not show Yedō, capital of the Tokugawa shōgunate since 1603—is superior to it in assigning to Japan's northern extremity an approximately correct latitude. Reland is some 6 degrees off in that respect. Clearly Reland did not follow any contemporary western models of delineating the shape and ascertaining the position of the Japanese islands, a conclusion amply supported by comparing his map with others made by Sanson, Blaeu, or Cassini. What, then may his sources have been?

Reland's map, in the fashion of the times, is richly decorated with marginal figures. A detailed examination of these reveals that the figures depicting certain aspects of Japanese life and certain types of Japanese costume are taken without change from Arnoldus Montanus' great work on the Dutch embassy to the Yedō court, first published in 1667 and splendidly illustrated with over a hundred engravings.[4] The coats of arms of Japanese nobles are taken from Montanus, and

[3] "Particulam hanc quae sinum oppidi Nangasacki exhibet, descripsi ex inedita mappa quae penes me est, in qua meorum aliquis popularium insulam Firando ubi olim nostri sedem habuerunt et quicquid est insularum litorumque ab illa usque ad Nangasacki deformaverat." (The details of the bay and city of Nagasaki I have taken from an unpublished map in my possession in which one of my countrymen described the island of Hirado, once occupied by us, and all of the islands and the coastline from Hirado to Nagasaki.) ". . . hac ipsa mappa . . . communicata mecum ex bibliotheca. . . . Benjaminis Dutry . . . magistri societatis Indicae Orientalis." (. . . this map . . . came to me from the library of Benjamin Dutry, Director of the East India Company.)

[4] Montanus, Arnoldus: *Ambassades mémorables de la Compagnie des Indes Orientales et des Provinces Unies vers l'Empereur du Japon* . . . Amsterdam, 1680.

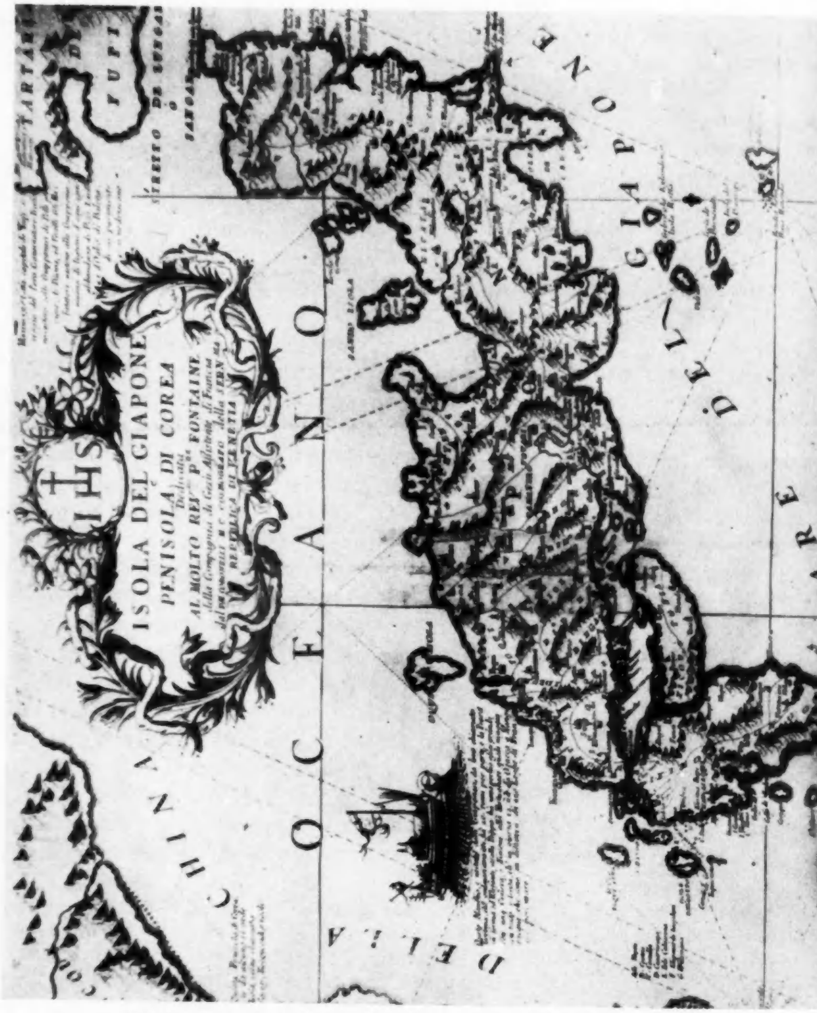

FIG. 2. *Isola del Giappone*, by Vincenzo Coronelli, Venice, 1696.

supplemented by information from François Caron's report on Japan and Siam, first printed in 1662.[5] The fact that the crest of the Tokugawa is shown as the coat of arms of the Emperor of Japan indicates that Reland, like most students of Japan of his time, did not realize the relative positions of the shogun and the hereditary Emperor, the Dairi.

The sixty-six feudal divisions of Japan indicated on Reland's map were first shown on a map compiled by a Portuguese Jesuit, Father Antonio Cardim, from Japanese sources, in 1646.[6] Father Briet's map[7] (Fig. 3), compiled during the

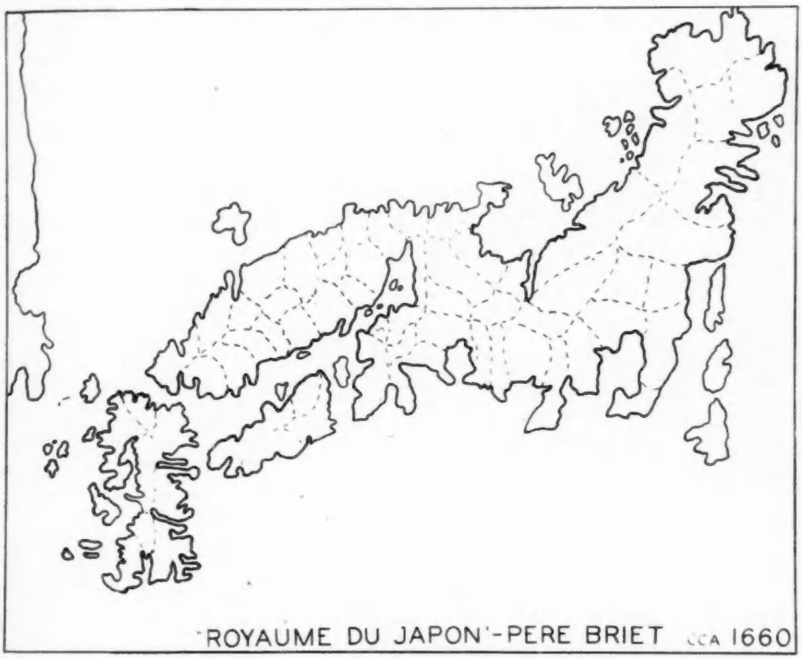

FIG. 3. *Royaume du Japon*, by Père Briet, Paris, before 1660.

[5] Caron, François: *Rechte Beschryvinge van het Machtigh Koninghrijck van Jappan* . . . s'Gravenhaage, 1662; cf.: *Recueil des Voyages . . . de la Compagnie des Indes Orientales*, vol. V., pp. 301 ff.; Amsterdam, 1648.

[6] Boxer, *op. cit.*, p. 5.

[7] *Royaume du Japon*, désigné par le Père Ph. Briet de la Compagnie de Iesus sur les mémoires des Pères de la mesme Compagnie. A Paris, chez Pierre Mariette. n.d.

latter part of the 17th century and published in Paris by Mariette prior to 1660,[8] is the first printed map to show the feudal provinces, but this map is a rather poor one concerning details of the Japanese coastline. It suggests that Lake Biwa is an inlet of Osaka Bay. Reland's map seems to be the first Western map to give not merely the location and names of the feudal "Kuni" in Latin, but also in Japanese characters. It is when we turn to the outer dependencies of Japan, however, that we encounter indications of the nature of the sources on which Reland based his map.

The problem of the northern islands of the Japanese archipelago was one of the great cartographic puzzles of the Pacific. For nearly three centuries the true nature of the lands north of Honshu remained a mystery, and it was not until the geographical results of the voyages of Russian navigators, especially Bering and Bellingshausen, were charted by Bellin, Mueller, and Buache that the confusion prevailing in the northwest Pacific disappeared.[9]

The first report of the existence of lands north of Honshu was sent to the Jesuit provincial in Goa by Father Aloisius Frões in 1565. According to this report, first printed in Cologne in 1574, there lies to the north of Japan and adjacent to it a great land, inhabited by savages. It is three hundred leagues from the city of Meaco (Kyōtō).[10] In 1619 Eliud Nicolai stated that this land is known as "Jezo or Ainoxomoti," meaning probably Aino Mushir, the isle of the Ainū, and that "it is a great island."[11] It was not until 1643, however, that Western navigators first charted the eastern shores of "Jezo," now known as Hokkaidō, and the shores of the two southernmost Kurils.

Acting upon rumors first circulated by Spain, and reporting the existence of Isles of Silver and Gold somewhere between 29° and 34° north latitude in the western Pacific, the Dutch East India Company dispatched two expeditions to locate these islands.[12] The first of these expeditions, commanded by Quast and Tasman, left Batavia in 1639, discovered the Bonin and Volcano islands, but could not find the fabulous lands of precious metals. Thereupon Antonio Van Diemen, then governor-

[8] "Pierre Mariette, the earliest known of the Mariette family, died December 18, 1657." Cf.: Fordham, H. G.: *Studies in Carto-Bibliography, British and French . . .* Oxford, 1914, p. 162.

[9] Cf.: Wroth, L. C.: "The Early Cartography of the Pacific," *The Papers of the Bibliographical Society of America*, vol. 38 (1944), no. 2, pp. 207–15, 217–27; Teleki, Graf Paul: *Atlas zur Geschichte der Kartographie der Japanischen Inseln:* Budapest, 1909.

[10] Cf.: *Rerum a Societate Jesu in Oriente Gestarum volumen*, Coloniae, 1574, p. 426; Siebold, P. F. von: *Nippon, Archiv zur Beschreibung Japans*, Berlin, 1930–31, vol. I., p. 151, note 16; Delisle, Guilleaume: "Lettre de Monsr. de l'Ile sur le Japon," in: *Recueil des Voyages au Nord*, Bernard, J. F., ed., Amsterdam, 1715, vol. III, p. 54.

[11] Cf. *Newe und warhaffte Relation, von deme was sich in beederley, das ist, in den West- und Ost-Indien zugetragen . . . durch Eliud Nicolaian tag gegeben*, München, 1619. Ref.: Siebold, *op. cit.*, vol. I., p. 151, note 16.

[12] Wroth, *op. cit.*, pp. 208–09.

general of the Dutch East Indies, dispatched a second expedition consisting of two ships, the *Castricoem* and the *Braeskens*, under the command of Maarten Gerrits Vries. Vries' ships sailed north along the east coast of Japan, charted the eastern shore of Hokkaidō and of two of the southernmost Kuril Islands, Kunashiri and Etōrōfu, named respectively Staten Eyland and Companies' Land by Vries.[13] A chart drawn by Isaac de Graaf and now in the archives at the Hague shows the results of the voyage (Fig. 4). It implies that east of Etorofu, where the *Braeskens*

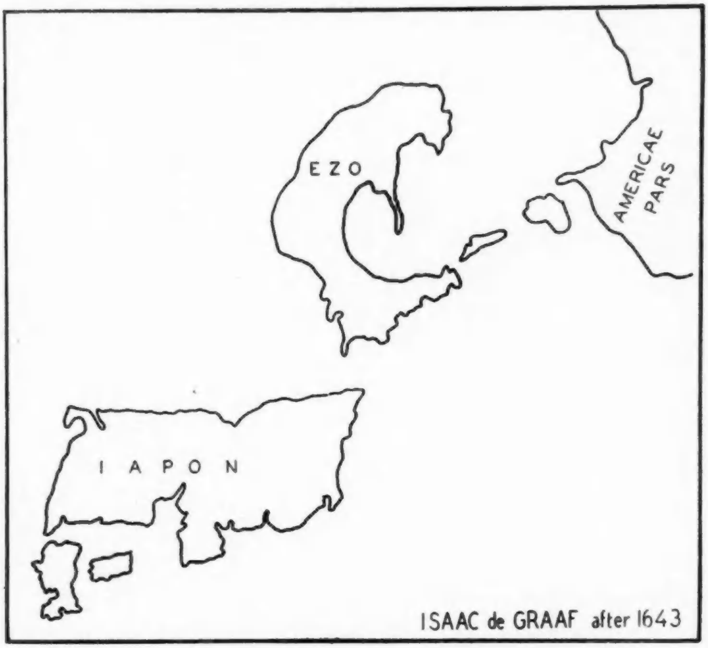

Fig. 4. Japan and the North Pacific, by I. de Graaf, MS, after 1643.

turned back, may have lain America.[14] The first printed map to show Vries' discoveries is Jansson's map of Japan, printed sometime between 1650 and 1654[15]

[13] "The earliest printed account of the Vries voyage seems to have been the *Korte beschrijvinghe van het Eylandt by de Iapanders Eso genaemt . . . inden Jare 1643, van't Schip Castricom*, in: Brouwer, Hendrik: *Journael Ende Historis verhael van de Reyse Gedaen by Oosten de Straet le Maire*, Amsterdam, 1646, pp. 95–104." Wroth, *op. cit.*, p. 210, note 18.

[14] Reproduced by Teleki, *op. cit.*, plates VI and XIX.

[15] Wroth, *op. cit.*, p. 210.

FIG. 5. *Nova et Accurata Iaponiae . . . descriptio,* by J. Jansson, ca. 1650.

(Fig. 5). Jansson, however, did not accept Vries' findings, or he may not have wanted to divulge his information entirely. He shows Companies' Land in the place of the American mainland of de Graaf's chart and he does not indicate that Hokkaidō is an island. The resulting confusion was to plague the minds and eyes and hands of cartographers for over a hundred years.

In addition to the rather nebulous Dutch reports on the northern Pacific, a Portuguese merchant, João de Gama, of Macao, sailing from China to Mexico via the northern route, seems to have had a glimpse of the Kurils. His findings were incorporated in a map, originally drawn by João Teixeira in 1649, redrawn on the basis of Vries' discoveries and engraved and published by Thévenot in 1664.[16] On this Teixeira-Thévenot map (Fig. 6) the north shore of Hokkaidō is indicated by a dotted line, leaving the decision as to the nature of that land, whether it was an island or part of the main, to the peruser of the map, and showing what may have been Companies' Land, or Etorofu, as Gama Land, possibly part of North America. It is not to be marveled at that Delisle, one of the foremost cartographic authorities of the early 18th century, states on his map of 1705 (Fig. 7) that one does not know whether Hokkaidō is connected with Japan or not. Delisle becomes even more explicit in his letter to Cassini, published in Amsterdam in 1715, on the subject of Japan. In this letter Delisle states that reports concerning the existence of a strait separating Honshu from Hokkaidō are confusing and uncertain. (It is unlikely that Delisle himself had ever seen the de Graaf manuscript chart, then still in the secret archives of the Dutch East India Company.) He emphasizes the fact that no maps of Japan made by Japanese cartographers and presumably containing reliable intelligence on the thorny problem of Hokkaidō were known to exist in Europe.[17]

It is interesting, in view of the highly controversial nature of the problem of the islands north of Japan, that Reland gives us a rather accurate map of the strait of Tsugaru between Honshu and Hokkaidō, and places on the south shore of the latter island the words "Yesso" and, in Japanese characters, "Matsumae." Matsumae was the northernmost outpost of the Tokugawa, a feudal fortress established in 1605 on the southwestern extremity of Hokkaidō. This bit of information, together with the legend "Korean Kingdom" appearing on the two tongues of land protruding along the northern margin of Reland's map, indicates that Japanese sources may have been used by the compiler. What, one might ask, was the state of the cartographical knowledge among the Japanese during the 17th century, the period preceding publication of Reland's map?

[16] In Thévenot, M.: *Relations de divers voyages . . .* , Paris, 1663, vol. I., seconde partie. Cf.: Wroth, *op. cit.*, p. 211–12.

[17] Delisle, Guilleaume: "Lettre de Monsr. de l'Ile sur le Japon," in: *Recueil des Voyages au Nord*, Bernard, J. F., ed., Amsterdam, 1715, vol. III., pp. 32–43.

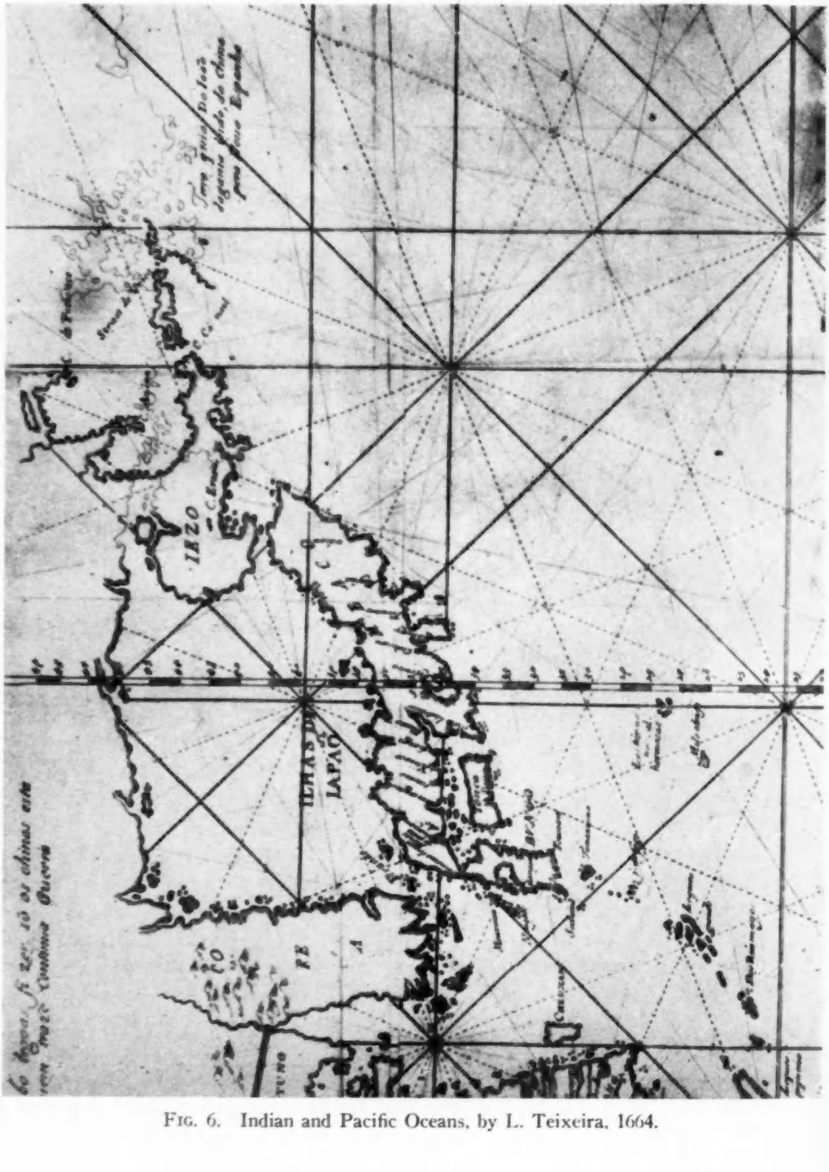

FIG. 6. Indian and Pacific Oceans, by L. Teixeira, 1664.

FIG. 7. *Carte des Indes et de la Chine*, by G. Delisle, 1705.

Western methods of surveying and mapmaking seem to have been introduced by the Dutch during the early Tokugawa era, probably during the Kwanei period (1624–1643).[18] That this may well have been the case is indicated by the permission given by Tokugawa Iyeyasu, the first shogun of that line, to the Spaniards to survey the coasts of his domain in 1611, since no native surveyors were available.[19] Higuchi Gonemon and Hojo Ujinaga seem to have been the first Japanese surveyors and mapmakers. They were trained by Dutchmen, one of whom, Schaedel, was a member of Vries' crew on the northern expedition of 1643. Schaedel was

[18] Gyōgi-Bosatsu, a Korean Buddhist (A.D. 670–749), is considered to have been the first maker of Japanese maps. The earliest known map of Japan, preserved in Ninna-ji temple near Kyōtō and dated 1305, is believed to be the copy of a Gyōgi type map of the Heian era. The Ortelius-Teixeira map of Japan, *Iaponiae Insulae Descriptio*, Antverp, 1595, first map of Japan printed in Europe, may have been based on such a Gyōgi-type map. Cf.: Ramming, M., "The Evolution of Cartography in Japan," *Imago Mundi*, vol. II., 1937, p. 18 (Fig. 8).

[19] Cf. Teleki, *op. cit.* Ramming, on the other hand, believes that the first land survey took place in 1605. Cf. Ramming, *op. cit.*, p. 19.

employed in Yedō for nine months, in 1650, to teach the elements of surveying and geometry to the Japanese. One of his students published a treatise on surveying in 1687.[20]

While the art of surveying and of the making of detailed topographic maps was not known in Japan until the introduction of surveying manuals, written by Jesuits in China and translated there into Chinese during the first half of the 18th century, large-scale maps of Japan were made even prior to the Tokugawa era, and the first small-scale maps of Japan were printed as early as 1651.[21]

That these Japanese maps, based to a large extent upon Western models, were known outside Japan is indicated by many facts. When Vries sailed in quest of the Gold and Silver Islands in 1643, among the maps and charts carried aboard his ship there were "two maps of the Gold Island, as they are depicted on the Japanese 'Byōbu' [folding screens]."[22] Even before Vries' time, maps of the Pacific showing

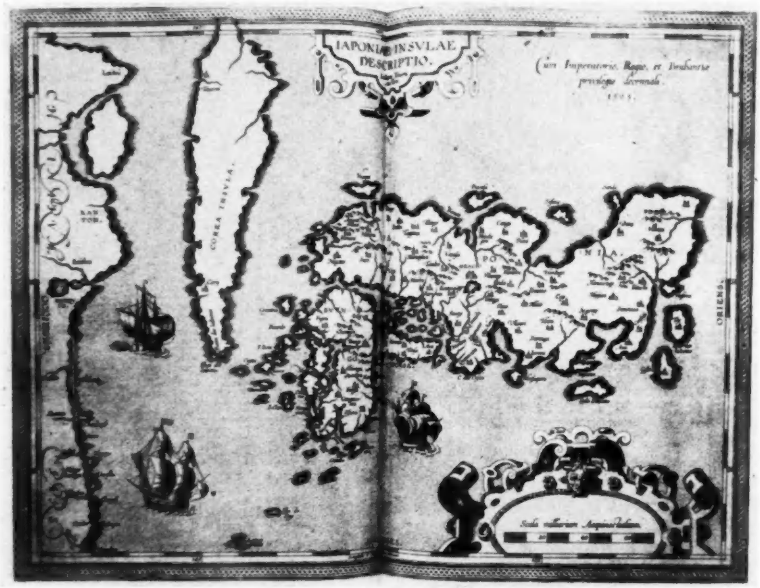

FIG. 8. *Iaponiae Insulae Descriptio*, by L. Teixeira, 1595.

[20] Boxer, *op. cit.*, p. 13.

[21] "A map of 1651, preserved at the Imperial University of Kyōtō, is probably the earliest printed general map of Japan . . ." Ramming, *op. cit.*, p. 20. Also cf. Teleki, *op. cit.*, p. 104.

[22] Boxer, *op. cit.*, pp. 5–6.

the Japanese islands, such as Linschoten's map of 1596[23] (Fig. 9), indicate the influence of Japanese charts.[24] These early Japanese maps were probably copies of Portuguese portolans, corrected by the Japanese to give a more accurate description of parts of their islands. The charts themselves were transmitted to Europe partly through the commercial channels of the Spanish and Portuguese, later of the English and Dutch traders, and partly with the reports of the Jesuit fathers who were thoroughly familiar with most of Japan. One authority on the

FIG. 9. *Exacta et Accurata Delineatio . . . in regionibus China* [etc.], by A. Langren, 1596. (Note that North is to the left of the map.)

[23] Linschoten, Jan Huyghen van: *Exacta & Accurata Delineatio . . . in Regionibus China, Cauchinchina . . . Sumatra, Java . . . Timora, Moluccae, Philippinae . . . Insulae Japan & Corea.* In Linschoten's Itinerario, 1596 ed. (probably based on portolan, by Langren).

[24] Siebold, *op. cit.*, vol. I., pp. 176–77.

history of Tokugawa Japan asserts that the Dutch did not merely employ maps made by Japanese cartographers, as Vries had done. Certain secret maps of the Dutch East India Company, such as the Tasman-Quast manuscript maps of 1639, incorporated considerable Japanese cartographic information.[25] Kaempfer himself, our foremost authority on the Japan of the Middle Tokugawa era, states that he saw and consulted ". . . the Japanese Maps of those seas . . . several of them in different places, as at Yedō, in the palace of the governor of Nagasaki, in a temple near Osacca, and in several other temples."[26]

It seems certain in the light of these facts, that Japanese maps, made by Japanese cartographers and based to some extent at least on Japanese surveys—although the framework seems to have been mostly Portuguese and/or Dutch in origin—were fairly common within Tokugawa Japan and that several of them reached the workshops of Western mapmakers. Count Paul Teleki, in his authoritative survey of the cartographic history of Japan, reproduces a manuscript map of Japan, found in the French National Library in Paris[27] (Fig. 10). If we compare this map with

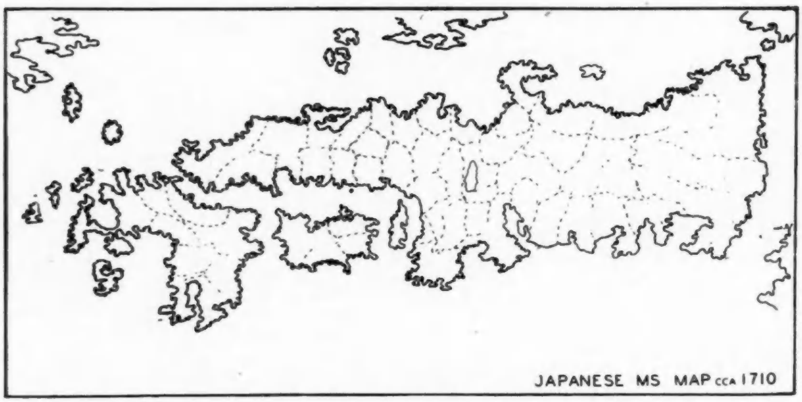

FIG. 10. Map of Japan, MS. by unknown author, ca. 1710.

Reland's the resemblance is striking. Not only do all place names used by Reland seem to be taken from this Japanese original, but the configuration of the coasts, and the otherwise incomprehensible error of latitude assigned to the northern end of Honshu, appear as a result of Reland's following the Japanese map and disre-

[25] Siebold, *op. cit.*, vol. I., p. 61.

[26] Kaempfer, Engelbertus: *The History of Japan* . . . London, 1727, vol. I., p. 68.

[27] In the Bibliothèque Nationale, Paris, reprod. by Teleki, *op. cit.*, plate XII. On the original map a MS. note on the margin refers to three maps in the British Museum, Nos. 74, 75, and 76, as being identical with the Paris copy.

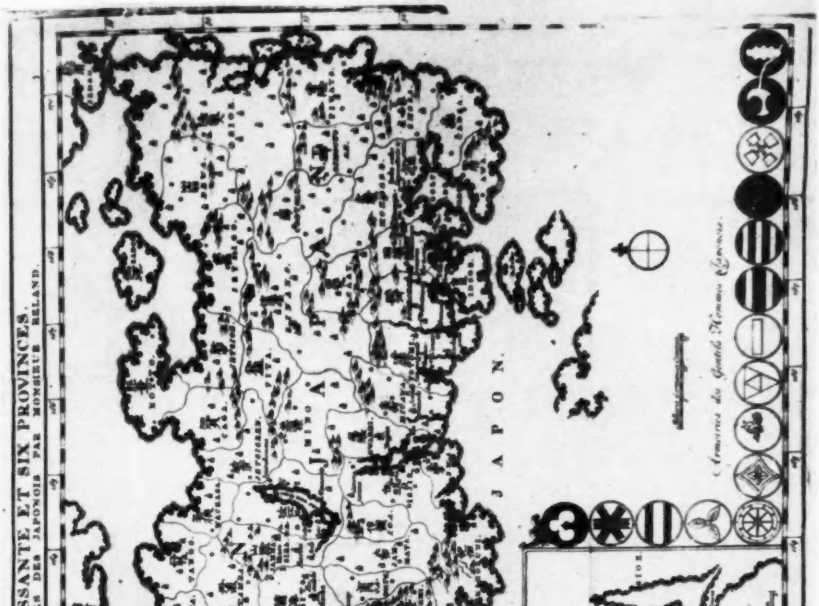

FIG. 11. *Le Japon divisé en soissante et six provinces,* by Adrien Reland, 1715.

FIG. 12. Map of Japan, by J. C. Scheuchzer, 1727.

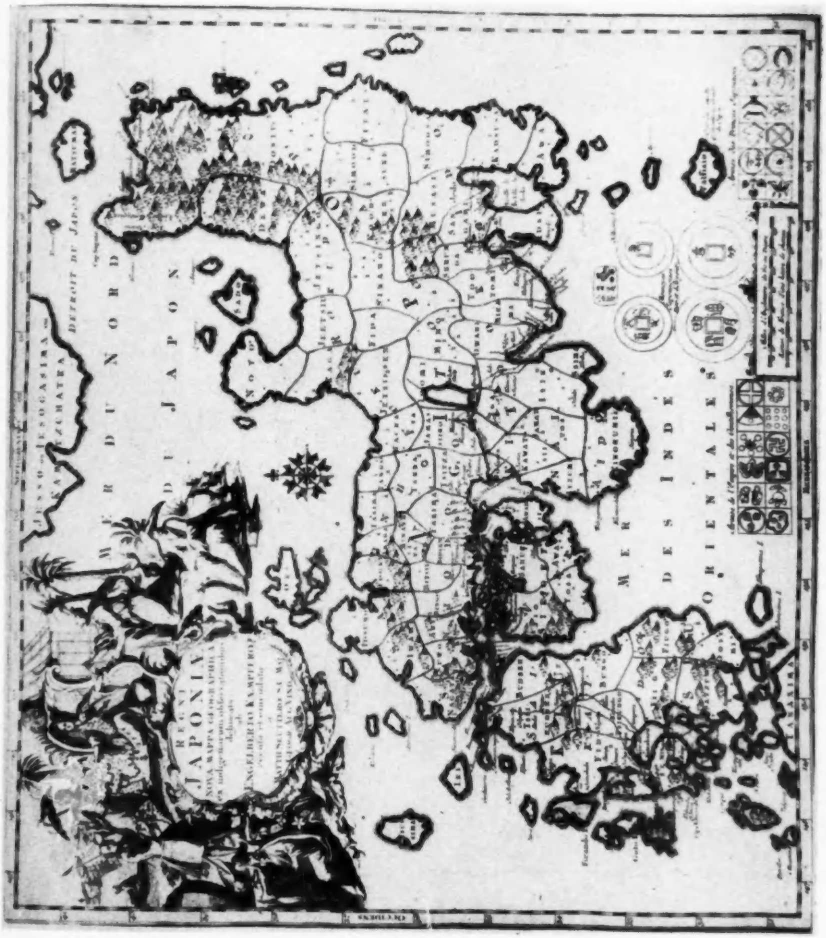

FIG. 13. *Regni Japoniae Nova Mappa Geographica,* by Seutter, 1730.

FIG. 14. *Niewe Karte van't Keizerryk Japan*, by I. Tirion, 1740.

garding European authorities on the subject. The confusion prevailing on the subject of the islands north of Japan may well have frightened one who was not a professional cartographer away from the use of Western maps, thus explaining the mixture of truth and error in the Reland map. Finally, what seems to have been the first printing of the Reland map, in a collection of voyages (Amsterdam, 1715), indicates both in the title of the map and in the text that Reland based his work on Japanese maps[28] (Fig. 11).

The continuing influence of Reland is evident in maps of Japan published during the first half of the 18th century. Scheuchzer's map, drawn to illustrate Kaempfer's great work on the island empire, was published in London, in 1727 (Fig. 12). In naming the feudal provinces, Scheuchzer follows Reland closely, changing only the transliteration of the "Kuni" names. Seutter's map of Japan, published in Vienna in 1730 (Fig. 13), seems to be a copy of the Scheuchzer map of 1727, except for omitting the Japanese characters from the "Kuni." And, finally, Tirion's map of Japan published in Amsterdam sometime after 1740 (Fig. 14), shows the first signs of a correct interpretation not merely of the sixty-six feudal provinces, named here as in Reland's map, but giving for the first time the names of the major geographical regions of Japan, including Tokaidō, Hōkurōkudō, and Nankaidō.

[28] "On donne ici une Nouvelle Carte du Japon, fort estimée & dressée par Mr. Reland sur la Carte d'un Japonois." Delisle, *op. cit.*, footnote on p. 43.

GEORGE HENRY PRIMMER, 1889–1946

J. HERBERT BURGY

Scarcely two months after he had assumed headship of the Department of Geology and Geography at Bradley University, George Henry Primmer died, on last November 18, following a twenty-day illness. His wife and a foster daughter survive him.

Mr. Primmer was born on January 23, 1889, in Champaign County, Illinois. He received his early education in the schools of that area and later attended the Illinois State Normal University where, in 1913, he received the degree of Bachelor of Education. His graduate work was done in the field of geography, and he was granted a Master's degree from the University of Chicago in 1922, and the degree of Doctor of Philosophy from Clark University in 1933.

The greater part of Mr. Primmer's professional career was spent in teaching his chosen subject in the State Teachers College, Duluth, Minnesota. He went there as instructor in geography in 1922 after he had received his Master's degree and, except for leave of absence in the early thirties, when he fulfilled the requirements for the Doctor's degree, he was a member of the staff of the Duluth college for twenty years. He became head of the Department of Geography in 1933 and served in that capacity until he was granted leave of absence to accept wartime work in Washington in 1942. In addition to his Duluth teaching experience, he taught in the rural schools of Champaign County, Illinois, and assisted in the Department of Geography at the University of Chicago.

It is but natural that the Upper Lakes region, especially the so-called Arrowhead Country, was his primary interest in the field of geographic research. The subject of his doctoral dissertation reflects this: "The Influence of Location on the Evolution of Duluth, Minnesota." His concern with the utilization and conservation of natural resources is shown in a number of articles in *Economic Geography*, including "The Future of Lake Superior Iron Ore Supply," Volume X (1934), pp. 395–401; "Minnesota Forest Situation," Volume XI (1935), pp. 389–400; and "Isle Royale: Potential National Park," Volume XIV (1938), pp. 349–53. A paper on "The Iron and Steel Industry of Duluth: A Study in Locational Maladjustments" (with C. Langdon White) appeared in the *Geographical Review*, Volume XXVII (1937), pp. 82–91. His interest in the field of economic geography is further shown in three articles published in *Economic Geography* during the period from 1939 to 1941: "The Changing Vegetable Oils Trade of the United States," Volume XV (1939), pp. 69–74; "United States Soybean Industry" (same volume, pp. 205–11); and "The United States Flax Industry," Volume XVII (1941), pp. 24–30. Another paper, entitled "Pioneer Roads Centering at Duluth," *Minnesota History*, Volume XVI (1935), pp. 282–99, contributes to knowledge of the historical development of

northern Minnesota. To the *Journal of Geography* he contributed many reviews as well as "Adjustments to Climate in Mediterranean Asia," Volume XXXIV (1935), pp. 21–32. His last published writing, with John Helmberger as collaborator, was "Industrial Strength of Belligerents Compared," *Journal of Geography,* Volume XL (1941), pp. 255–59.

Mr. Primmer was elected to membership in the Association of American Geographers in 1939. He was also an active member of the National Council of Geography Teachers and ably served as its treasurer for several years. He was chairman of the Minnesota section of the National Council in 1924 and again in 1935. Other organizational memberships which he held included those in the Minnesota Academy of Sciences and the American Association of University Professors.

When the demand for geographers became acute during the recent World War, Mr. Primmer went to Washington, D. C., where, from 1942 to 1945, he carried on research for two different agencies. It was in the early summer of 1945 that he, together with four other civilian professors of geography, was selected by the Information and Education Division of the War Department to teach in the European Theater in the Army-sponsored institutions organized in the interests of GIs awaiting redeployment. Mr. Primmer was assigned to the Shrivenham (England) American University, and taught there during the two terms of its existence from July to December, 1945. After the closing of the University, he was transferred to Frankfurt, Germany, where he became affiliated with the Command Schools organized by the Army. From January to April he taught in Vienna, Austria, and from April to June in Regensburg, Germany. Just prior to returning to the United States he served in Germany for a short time as inspector of schools set up for children of American military personnel. His headquarters during this assignment were at Frankfurt.

I vividly recall a pleasant travel experience with Mr. Primmer in April, 1946, enroute from Frankfurt to Munich. He exuded enthusiasm, and considered his experiences in Europe as being very much worthwhile both from a professional and a personal point of view. He showed no sign of approaching illness, and his death came as a shock to friends and members of his family. During the last year of his life, Mr. Primmer had the privilege of traveling extensively in the British Isles, France, Germany, Austria, and Switzerland. This enabled him to revisit parts of western Europe he had seen during military service in the first World War.

JAMES WARREN BAGLEY, 1881–1947

ERWIN RAISZ

When the telegram came on February 19, 1947, announcing the passing-away of Colonel Bagley, it was a real shock for all who knew him. He retired from the Institute of Geographical Exploration, Cambridge, Massachusetts, only about a year ago, to return to his family estate at Fayetteville, Tennessee. It was in near-by Chattanooga where his failing heart beat its last.

James Warren Bagley was born on October 31, 1881, at Fayetteville, Tennessee, into a distinguished southern family. Even as a student he showed a marked interest in mathematics and engineering. He pursued his studies at Washington and Lee University, where he received a Phi Beta Kappa key. He was graduated in 1903.

His first work was with the United States Geological Survey, from 1905 to 1917. His assignments took him all over the United States and to Alaska, where he mapped the Chugach Range. In connection with this work he developed a panoramic camera which enabled a surveyor to photograph the entire circle of the horizon in only three sections.

During the first World War he became captain and later major in the Corps of Engineers. He saw service in this country and also in France. Together with Captain Moffett he developed the three-lens camera by which a much larger field could be photographed at a single flight than was possible with the single-lens camera. After the war he remained with the Army in active service. His chief interest was in airplane photography, to which field he contributed the "Bagley five-lens camera." He retired as Lieutenant Colonel in 1936, and in the following year became a Lecturer at the Institute of Geographical Exploration. His famous textbook, *Aerophotography and Aerosurveying*, was written here. Since his retirement in 1945 his work has been ably carried on by Major Edward S. Wood, Jr.

In 1911 James Warren Bagley married Agnes Stevens, who has been a most charming and loyal companion all through life. Three children also survive him: Samuel Stevens, who is on the family estate; Charles Thomas, a member of the faculty of the University of Tennessee; and Lucy Warren, a social worker in Vermont. There are four grandchildren.

A gentleman by tradition, a scientist by education, and an inventor by nature, Colonel Bagley was loved and respected by all who knew him. Although gentle and kind, he had an air of authority and was an able leader. In his work he was exacting, trying to get a mathematical solution to each problem, and the same exactitude was demanded from his students. He was teaching in one of the first private institutions where airplane photography was offered, and many new techniques which became of importance during the war were developed in his laboratories. Many of his students occupy important posts, thousands of men have been trained by his books, and Colonel Bagley's name is indelibly inscribed in the history of American photogrammetry.

REVIEWS AND ABSTRACTS OF STUDIES

INVENTORY OF THE WORLD'S MINERALS

Friedensburg, Ferdinand: *Die Bergwirtshaft der Erde.* Third Edition, 531 pp., maps, index. Ferdinand Enke Verlag, Stuttgart. 1944.

Students concerned with the world's mineral resources and mineral production will find this latest edition by Friedensburg the most complete coverage of the field in one volume today.

The author has described the salient points regarding the mineral deposits and the mineral production of 159 different political entities. In areas or countries where the mineral industries are of particular importance the text is augmented by the inclusion of maps and tables. Consistency in symbolization for mineral locations on all of the 53 maps included and comparability of production and reserve tables adds greatly to the usefulness of the volume. A valuable feature of the production tables is the inclusion of columns detailing the country's production as (1) a percentage of total world production for 1938, and (2) a percentage of its own consumption in the same year. Of unusual value also are the lists of references found at the conclusion of each country description. It is apparent that the author has had access to all the important pre-war sources of information relating to the minerals field. In some instances access was also had to works published in Allied countries long after the war had begun.

Several features of the volume detract somewhat from its usefulness. Chief among these is the scheme carried over from the earliest edition whereby the pre-World War I German colonies are still treated as part of the Deutches Reich. To a lesser degree confusion is found in the pattern of treatment of the Central-European countries. Austria, the Sudetenland, and Bohemia-Moravia are dealt with as integral parts of the German Empire. This is not unexpected, however, considering the date of the publication. Military censorship no doubt accounts for the lack of information regarding developments in the field of mining after 1939 as it pertains to Germany, Italy, and the Axis dominated areas.

In spite of the somewhat minor deficiencies apparent, the author has brought together the most complete and accurate information to be found in one volume on the mineral resources of the world.

Paul W. Icke
Department of State, Washington

CALIFORNIA NOMENCLATURE

Hanna, Phil T.: *The Dictionary of California Land Names.* Saunders Press, Claremont, California, 1946.

Man names himself and the land. From childhood on, names seem to intrigue him. In the United States, where names of men, in the sense of family names, commonly arouse scant interest, the focus is usually on place names. Geographers and those in closely allied fields have a vital interest in names on the land. Many investigators have spent much time tracing origins of place names, primarily in the hope that toponymy would further their understanding of the land and its inhabitation. Also, many have had to study and reach agreement on geographical names in order to eliminate or prevent widespread toponymical chaos.

Nowhere has place-name interest been greater than in California. Mr. Hanna's book is recent and further evidence of this. It represents a quarter-century of study and contains approximately 4,000 names. These range from names of desert water holes and ghost towns to mountain peaks and large cities. Accompanying each is indication of location (by county), explanation of origin, and (if the name is Spanish or is given Spanish pronunciation) correct pronunciation. The introduction presents, among other discussion, the general sources of California names, such as those based on natural conditions (Pine Valley, Coyote Well), personages or events (Stockton, Tragedy), other regions or places (Venice, Brynmawr), or on "hybridization" (Calexico,

Calneva). In addition, name-sources are indicated as Spanish, Indian, Spanish-Indian, Gold Rush, railway, etc. Attention is called to the preponderance of Spanish names. The latter pages of the book contain a useful listing of materials consulted by the author. These consist of books and pamphlets, newspapers and periodicals, manuscripts, and maps—a total, in all, of more than 350 references. Several of the references are place-name studies significant in themselves. Important among them are: A. L. Kroeber, "California Place Names of Indian Origin," *University of California Publications in American Archeology and Ethnology*, Vol. 12, No. 2 (June, 1915), University of California Press, Berkeley, 1916; Nellie Van De Grift Sanchez, *Spanish and Indian Place Names of California*, A. M. Robertson, San Francisco, 1922; and George Stewart, *Names on the Land*, Random House, New York, 1945.

The flavor of a book such as Mr. Hanna's can be imparted only by quotation. For example, San José, a city in Santa Clara County, is described as follows: "San José de Guadalupe was the first pueblo, or 'city,' to be founded in California. It was settled on November 29, 1777, by five colonists who had come from Sonora, Mexico, with Juan Bautista de Anza. All previous settlements in California had been either missions, in charge of Franciscan friars, or presidios, where the protecting soldiers were quartered. Governor Felipe de Neve personally selected the site for the community on the Río Guadalupe (hence the 'de Guadalupe'), and the city was named in honor of St. Joseph, spouse of the Virgin Mary. San José is historically renowned likewise as the meeting place (Dec. 17, 1849) of the first California constitutional legislature. The modern city was incorporated March 27, 1850." Many of the names carry descriptions much less complete than the one just noted and a number of place names are missing entirely. However, the author is the first to admit shortcomings, and he regards the book as an outline which is far from complete. Presumably many of the present gaps will be filled by a separate undertaking now in progress at the University of California at Berkeley, where a group of investigators is compiling a similar "dictionary" of larger scope. Mr. Hanna's book contains not a single map. There are, no doubt, good and practical reasons for so serious an omission, but certainly the book's usefulness would be greatly enhanced by the addition of even a few simple black-and-white maps. As it stands, it is a useful contribution to the toponymy of California.

ROBERT M. GLENDINNING
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ALABAMA'S INDUSTRIAL OPPORTUNITIES

A major concern of the Alabama State Planning Board is the development of industries within the state, and, in the process, to stimulate insofar as possible local persons or firms to undertake industrial ventures which fit either local resources or local markets sufficiently well to give reasonable prospect of success. To inform interested parties of industrial opportunities and to give a basis for preliminary understandings of the investment processes, and economic prospects of various types of manufacturing, the series of volumes, *Alabama's Industrial Opportunities*, has been undertaken. The project anticipates the compilation of ten volumes under the same title, of which the following six have been completed to date:

Volume	*Title*	*Publication Date*
I	Lumber and Timber Basic Products; Furniture and Finished Lumber Products	December, 1945
II	Food and Kindred Products; Tobacco Manufactures	February, 1946
III	Textile-Mill Products and Other Fiber Manufactures	April, 1946
IV	Apparel and Other Finished Products Made from Fabrics and Similar Materials	June, 1946
V	Paper and Allied Products; Printing, Publishing, and Allied Industries	August, 1946
VI	Chemicals and Allied Products; Products of Petroleum and Coal	October, 1946

This series has much material of value to the geographer, particularly one interested in the economic geography of the United States. While drawn primarily from the standpoint of Alabama, comparative data relating to the na-

tion, the Southeast, and all other states are given in tabular and map form.

The various volumes treat major groups of industries as classified by the census. Each industry is described in terms of distribution—in Alabama, Southeast, and the Nation—in terms of number of establishments and value of products in 1939, the tabulation being accompanied by a page-size map of the United States showing the distribution of the industries over the country as a whole. For each industry a further analysis is presented, breaking down the cost into: salaries and wages, materials and supplies, fuel, electrical energy, and other costs and profits. Value of products and value added by manufacture are also stated.

In a further breakdown, power and fuel data are stated in terms of energy consumed per unit of product and coal consumed in tons per unit of product. Raw materials are also listed, together with source, where appropriate.

Markets are briefly treated in each instance, with estimated percentage given as to the prospects for export, for industrial consumption, and consumers' use. The estimated market for the nation, the region, and Alabama is given in dollars and compared to current production figures, and deficiency and surpluses are derived in each case. State and region figures on employment in 1929 and 1939 are presented, together with data on average wage.

For each industry there is shown a materials flow chart indicating the raw materials and energy applications at various steps in the manufacturing process, together with intermediate and end products of the operation. These charts, one for each of about 500 industries, provide a basis for much better understanding of industrial processes than that possessed by most geographers. Every geographer knows that in a small sawmill the prime raw material is logs and that the sawing operation produces lumber or timber, sawdust, and slabs. Few could similarly trace the more complex flow of materials through a cannery handling fish, crustacea and mollusks, or through a beet-sugar refinery, a macaroni factory, paper and paper products, woolen and worsted manufacturing, or soap and glycerin production. These and hundreds of other industries are uniformly described in this series of volumes which, when complete, will cover all industries listed by the census.

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REGIONAL PLANNING IN BRITAIN

English County: a Planning Survey of Herefordshire. A publication of the West Midland Group on Post-War Reconstruction and Planning. Faber and Faber, Ltd., London, 1946.

This first publication of its type for Britain sets an exceptionally high standard, both as to content and appearance. It includes sections on "The Land" (physical setting, geology, land resources, climate, landscape); "The People" (population density and distribution; population change); "Economic Life" (industry, planning, labor, land utilization, agriculture); and "Social Environment and Public Services." The editors have included numerous maps, both detailed and generalized, in color, and have enriched the pages with excellent photographs, some in color. Furthermore, the most important photographs have accompanying sketch maps in which the landscape shown is analyzed—a device too often neglected by American geographers. The compilation and presentation of the material on the county is so complete that it is difficult to find any geographic element which has been omitted. There are maps of archeological remains, bus service, land use regions, library services, areas tributary to secondary schools, inaccessibility, and classification of the quality of houses.

This volume, after an excellent presentation of the geographic and sociologic data, includes a brief appendix in which general recommendations for the future are proposed. This represents a step beyond which most American geographers hesitate to go, and the findings include the following point-blank statements:

1. The development of all land should be controlled by the State.
2. Life of all existing and proposed buildings should be licensed.

Local recommendations applying to Herefordshire include the following:

1. Herefordshire can best contribute to the national and regional economy by remaining a predominantly agricultural county.
2. Suitable manufacturing industries should be developed in the county as an adjunct to its agricultural development.
3. The excessive decline in population of the county as a whole, of some of the market towns, and especially of the rural areas, should, if possible, be checked.
4. The great scenic attraction of the county should be safeguarded by means of a flexible scheme of landscape control.

While it is difficult to find fault with such a comprehensive piece of work, the reviewer believes that the relations of Herefordshire to the surrounding counties have been neglected; this is apparent visually in the very sharp and heavy black political boundary which distinguishes the county limits on nearly all the maps. Some attention to Hereford's interdependence and relations to other English counties would have added to the value of the book. This lack is particularly strange since the authors have recognized relations with America by reproducing a page from *Life* dealing with Hereford cattle on an Oklahoma ranch.

A somewhat inadequate index ends the volume. Not all maps are equipped with stated scales, but many Americans will appreciate the use of acres, miles, and inches in place of the units of the metric system. Forthcoming planning surveys now in preparation include a study of Birmingham, Wolverhampton and the Black Country. Geographers who worked on the study at hand include Mr. K. M. Buchanan and Mr. A. W. McPherson of the University of Birmingham, Dr. L. Dudley Stamp of the University of London, and Mr. R. H. Kinvig, also of the University of Birmingham.

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